EVALUATION OF LABORATORY MODEL GRAIN CLEANING AND SEPARATING EQUIPMENT

(Part I)

by

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INTRODUCTION

The total mechanization for separating whole kernels of grain from broken kernels, foreign materials, light materials, and other grains in a grain sample may be desirable for the U.S. grain grading system. In order to develop rapid and accurate procedures and methods for grain cleaning, an earlier study, "Review of the State of the Art in Grain Cleaning," was conducted to select promising model of laboratory grain cleaners from throughout the world. Based on a literature review and survey of manufacturers specifications, two models were selected:

1. Mini Cleaner and Grader, Model Labofix, manufactured by MCK Maschinenbau in W. Germany;
2. Laboratory Cleaner-Separator, Model N.S.L., manufactured by Tripette & Renaud in France.

However, these models were selected without laboratory testing. Therefore, it was necessary to conduct a research project to test these models with grain samples.

The main objectives of this project were:

1. To conduct a series of tests for the two selected models of laboratory grain cleaners with a reference model of Carter-Day Dockage tester XT3, which is currently used in the U.S. grain grading system;
2. To analyze the test results statistically for accuracy, precision, reproducibility, applicability and ease of operation of each grain cleaning model; and
3. To evaluate whether or not these models will be applicable for the grain grading system in the United States.

REVIEW OF LITERATURE

A large number of research projects have been done on the analysis and evaluation of grain separation. The most widely used grain cleaner is an air-screen machine which separates according to the dimensions, shape, and terminal velocity of the grain particles. Some other types of machines separate grain kernels based on the electrical properties.

Chung and Lee (1985) studied the physical properties of rice and corn. They reviewed physical dimensions of grain, such as length, width and thickness, which varied according to the variety, environmental conditions, temperature, and moisture content. The true density ranges from 1019 kg/cu.m to 1387 kg/cu.m for rice, and 1190 kg/cu.m to about 1370 kg/cu.m for corn, depending on the variety and the variation in moisture content. Bilanski et al. (1962) measured the terminal velocities of one variety of wheat, barley, corn, soybeans, small and large oats, alfalfa, and flax in still air. Song and Chung (1989) studied the physical properties and terminal velocities of various fractions in corn samples. The study showed that no machine can separate the impurity completely from a given grain sample without any grain loss because of the size distributions of the different fractions. However, it is possible to separate the light materials from whole kernels using an aspirator or a combination of geometric properties. They also studied the effect of shape factor and Reynolds number on the drag coefficient of corn.

Chung and Converse (1971) studied the effect of moisture content on some physical properties of corn and wheat. They studied the changes in these properties caused by changes in moisture content related to both adsorption and desorption of moisture, and examined the effect of kernel shape and size on corn packing characteristics. Chattopadhyay (1983) studied physical properties of bran rice germ and broken grain including average particle diameters, terminal velocity, and specific gravity. He found that moisture conditioning which raised moisture content could increase the terminal velocities of germs and brokens and thus separation efficiency.

In sieving or screening, two types of screens, flat and rotary screens, are generally used. The

screens are rotated or vibrated to bring all the particles into contact with the openings. For flat screen, three different mechanical motions are involved in the separation process. These motions are oscillation, vertical vibration, and gyration.

Chung et al. (1986) conducted a research project named "Review of the State of the Art in Grain Cleaning". Information related to a total of 1,639 models of grain and seed cleaning equipment was collected from throughout the world based on a literature review and survey. It was found that 70% of the total models are of the following types: air-screen separator, screen separator, aspirator, indented cylinder separator, and rotary cylinder cleaner-grader.

Lee and Winfield (1969) studied the influence of oscillation frequency, entrance condition, air distribution along the sieve, and sieve-lip angle on grain loss from the upper combine sieve at medium and high input rates. They found out that increasing the oscillating frequency at a given input rate increased the agitation of the material on the sieve and reduced grain loss. They also found that increasing the sieve-lip angle from 30 to 36 degree reduced the grain loss. Nepomnyashchii (1982) investigated theoretically and experimentally the process of separating grain with a flat sieve. The kinetics of the process were described and indicators of efficiency and quality of cleaning were calculated in relation to cleaner operating parameters.

It was found from some of the experiments that separation operations were affected by the feed rate of the mass flow, and the moisture content of the grain mass. Paltik (1979) investigated the effect of the amplitude and frequency of oscillation of a vibrating screen with an unsteady curvilinear motion on its sieving capacity. Several experiments were conducted under conditions of different combinations of feed rate, amplitude and frequency of oscillations. The interaction between these factors was examined. Paltik also evaluated the performance of a model screen activated eccentrically to provide a circular path, or an elliptical path with the major axis either horizontal or vertical. Experiments were done under different conditions, and results were analyzed to determine the effect of vertical and horizontal acceleration, louvre setting, inclination of the sieve, and moisture content of the grain mass

on separation capacity and efficiency.

The vertical screen separator performs the same basic function as a conventional flat screen but offers significant advantages over the flat screen (Brandenburg, 1977). In machine operation, a mixture enters the machine at the top and flows outward to the rotating screen. Seeds then move down the screen's inner surface in a spiral path parallel to edges of the auger flights. Small seeds and other small particles pass through the screen holes, but larger materials are propelled downward and out the bottom of the cylinder by the relative screen-auger motion (Brandenburg, 1977).

Jan (1974) studied some of the basic factors affecting the performance of a rotating separation drum. The separating efficiency of a horizontal rotating perforated drum was affected primarily by the axial velocity of the straw-grain mixture. The axial velocity of the mixture was determined by feed rate, drum rotational speed, and the velocity and volume of the conveying air. Long (1969) developed an equation of motion for wheat kernels as they pass through a straw mat under the influence of centrifugal force in a rotary device. The study indicated that efficient centrifugal separation in the experimental rotor required sufficient agitation to prevent kernel lodging within the sample.

The separation principles for both flat and vertical rotating screen are based on width and thickness of grain kernels. The indented cylinder and indent disk are the two general types of separators to separate particles based on length.

The indented cylinder separator consists of a rotating, horizontal cylinder and a movable, horizontal separating trough. The inside of the surface of the cylinder has small, closely spaced indentations that may be hemispherical, cylindrical or tapered. As the cylinder rotates on its axis, the short particles of a seed mixture that fit into the indentations are lifted and discharged into the trough (Brandenburg, 1977).

Sucher and Pfost (1964) examined the effects of feed rate, cylinder speed and its slope, opening type and size on performance and efficiency of a cylindrical grader in removing contaminants from a corn sample. The interactions between feed rate and cylinder slope were significant in some of the

tests.

Fouad (1980) studied the effect of cell configuration on length grading of beans. He indicated that the conventional trapezoidal cell of an indented cylinder separator gave poor length grading of agricultural grains. He conducted a systematic study to establish the optimum parameters of the cell design. A new cylindrical cell was designed, which showed a better separation effectiveness in the case of beans.

Various devices were used to collect separated materials. The most popular device is a cyclone collector. Yamashita (1982) studied separating efficiency, uniformity of the air velocity and differences in materials with a horizontal cyclone. He found that separation accuracy was affected by the uniformity of air velocity distribution, and the effect of shape of the materials was remarkable.

Whitney (1968) developed a prediction equation for separation system which included the system parameter and physical cbaracteristics of the particles. Preliminary study revealed that separation of particles from the air stream was dissipating particle impact energy. Results of system operation with soybeans, sorghum, and wheat indicated that feed rate and concentration of grain at a given size class have little effect on separation.

Another interesting approach in studying grain cleaning is to apply the theory of stochastic process, since the motions of particles in air or on the sieve are random. Huynb (1982) developed a mathematical model to quantify the threshing and separation process of cereal crops in a conventional combine by using what he called "stochastic process". Unfortunately, the theory he used is more statistic than stochastic.

Chiang (1980) developed a special case of stochastic process, which has the so - called Markovian property. By Markovian property, it is implied that the probability for the system to make a transition to any state of the process only depends on the presently occupied state. Song and Chung (1989) developed anotber mathematical model for a grain cleaning process based on the Markovian property. To predict the separation efficiency and grain loss, a stochastic compartmental model was

developed for a constant feed rate condition which is common either in the laboratory or in the commercial grain cleaning process.

Previous research work showed that moisture content of grain mass affected terminal velocity, and sometimes separation efficiency. It is recommended that more work to be done on size distribution and on the measurement of terminal velocities of various solid grains and broken kernels at different moisture content, and the effect of impurity level on the separation efficiency for various grains.

MATERIALS AND METHODS

A. Test Samples

The test samples used to evaluate the laboratory grain cleaning equipment in this study were five major U.S. grains:

1. Hard red winter wheat
2. Durum wheat
3. Barley (six-row)
4. Yellow dent corn
5. Soybeans

These grain lots were obtained from the following locations: Federal Grain Inspection Service, Kansas City, MO; Manhattan Milling Company, Manhattan, KS; the Department of Cereal Technology, North Dakota University, Fargo, ND; and Agricultural Research Service, the U.S. Department of Agriculture, Pullman, WA.

B. Equipment

Equipment tested are tabulated in Table 1.

TABLE 1. Equipment Tested in the Project.

Brand name	Model	Manufacturer	Country
Mini Cleaner & Grader	Labofix	MCK Maschinenbau	W.Germany
Laboratory Cleaner-Separator	N.S.L.	Tripette & Renaud	France
Carter-Day Dockage Tester	XT3	Carter-Day	U.S.A.

C. Preliminary Test

Preliminary testing was done by using the Carter Day Dockage tester "XT3" (CD-XT3) with various grain samples. The results of each cleaning operation are presented in Table 2.

TABLE 2. Fractions of Sound Kernels and Impurities of U.S. Grains Separated by Carter Day Dockage Tester XT-3 (% Wt.).

Impurity level = medium
Moisture Content = 8 - 10% (W.B.)

Fraction Retained	Sieve	Wheat	Durum	Corn	Soybean	Barley
Light materials[1]		0.72	0.29	1.20	0.72	0.08
	Riddle	#2	#25	-	-	#6
Foreign materials		0.87	0.31	-	-	0.15
	Top sieve	#4	#5	#3	#3	#8
Sound kernels		91.65	85.10	82.80	82.58	99.67
	Middle sieve	#2	#2	#2	#2	#6
Broken & shrunken kernels		6.90	4.35	10.50	16.70	0.06
	Bottom sieve	#2	#2	#2	-	-
Broken kernels		trace	0.15	2.90	-	-
Powdered materials		0.31	9.48		trace	0.05

[1] = Feed and air control settings were adjusted to the specification of FGIS, USDA

The impurities in each grain sample consisted of five fractions; namely, light materials, foreign materials, broken and shrunken kernels or splits, and fine or powdered materials. Depending upon the grain type, the level of impurities ranges that we found were from about 0.4% to 17.0%. However, the sound kernel fraction separated by the CD-XT3 model retained a considerable amount of impurities, such as broken and shrunken kernels, which had to be separated further by hand. The residual impurities in the sound kernel fraction were, therefore, separated in part by hand and by the N.S.L. and Labofix models in order to collect the pure sound kernel fraction.

D. Experimental Design

The experimental design for the project was developed to evaluate the accuracy, precision, reproducibility, applicability, and ease of operation of each individual unit of cleaning equipment tested. The significant parameters investigated in this research were:

1. The five U.S. crops;
2. Two levels of moisture content, 11% and 15% (W.B.), selected to determine the effect of moisture content on the performance and efficiencies of each cleaning unit;
3. Three levels of impurities, 5%, 10%, and 15%, manually prepared and used to determine the effect of impurity level on the cleaning efficiency;
4. Two units of each model; and
5. Three replicates of each test sample, used for testing the reproducibility of each model.

In order to evaluate the cleaning operation of each model, removal efficiencies were determined by calculating a material balance of impurities on an input-output basis.

$$\eta_{IMP} = \frac{(IMP)_{out}}{(IMP)_{in}} x\ 100 \qquad [1]$$

where η_{IMP} = overall removal efficiency (%)

$(IMP)_{in}$ = total mass of impurities in test samples before separation

$(IMP)_{out}$ = total mass of impurities removed from test samples.

Total mass of impurities in the grain samples consisted of three fractions; namely, light materials (LM), foreign materials (FM), and broken, shrunken, and shriveled kernels or powdered particles (BSSP). In order to calculate the removal efficiency of each component of impurities, the following formulas were used:

$$\eta_L = \frac{(LM)_{out}}{(LM)_{in}} x\ 100 \qquad [2]$$

$$\eta_F = \frac{(FM)_{out}}{(FM)_{in}} x\ 100 \qquad [3]$$

$$\eta_B = \frac{(BSSP)_{out}}{(BSSP)_{in}} x\ 100 \qquad [4]$$

where η_L = removal efficiency of light materials (%)

η_F = removal efficiency of foreign materials (%)

η_B = removal efficiency of broken materials (%)

$(LM)_{out}$ = mass of light materials removed from samples

$(FM)_{out}$ = mass of foreign materials removed from samples

$(BSSP)_{out}$ = mass of broken, shrunken, shriveled kernels or powdered particles removed from samples.

For the statistical analyses, a factorial experiment in a completely randomized design was applied to analyze removal efficiencies observed at all factor-lever combinations of the

independent variables. All the statistical analyses were done using the "GLM" procedure in the SAS (1985) software package.

The project dealt, essentially, with total impurities versus sound grains. Therefore, the definitions used in the current system for grading grain in the U.S. is not practically applicable to this research project. In order to evaluate the removal efficiencies of the three laboratory types of grain cleaning equipment objectively, various fractions of impurities of grains were defined in this laboratory test procedure, and the terms were applied to the calculation of efficiencies of cleaning units.

Light material was defined as all matter separated by an aspiration system. Foreign material was defined as all matter removed by a scalper. Powdered particles were defined as all matter passing through the middle or bottom sieve of CD-XT3. Broken and shrunken kernels were defined as all broken and shrunken kernels removed either by cleaning equipment or hand-picking. Sound kernels were defined as whole kernels with less than 1/4 of kernel removed, and without any impurities.

Since broken and shrunken kernels are not clearly defined by the U.S. grain grading and inspection system, some portions of these fractions are subdivided as shown in Table 3. The proportion of each component of impurity in test grain samples is important in the determination of removal efficiencies of grain cleaning units. Therefore, Tables 3 and 4 are based on the preliminary tests in the laboratory and a series of discussions with concerned parties for the project, and confirmed at a conference with Dr. Don E. Koeltzow, Don Osterkamp, and Eugene Kerfeld from the FGIS, USDA, Kansas City, and Dr. James Steele and Harry Converse from the Grain Marketing Research Laboratory, USDA, Manhattan, KS, held at the Department of Agricultural Engineering, Kansas State University, on April 28, 1988. The preparation of sound kernels was further discussed at a meeting with Dr. Koeltzow and Mr. Osterkamp held at the FGIS, Kansas City on May 11, 1988, since the current definition of sound kernels is not

TABLE 3. Definition of Various Fractions of Broken and Shrunken Kernels Prepared in the Laboratory.

Fractions / Grains	BM#1	BM#2	BM#3	PM
HRW Wheat	broken kernels cross-sectioned	#4	$\frac{\#2}{\#2}$ + *a	#2
Durum	broken kernels cross-sectioned	$\frac{\#5}{\#2}$	#10 + *a	#2
Corn	broken kernels hand-picked	$\underline{\#3}$	$\frac{\#3}{\#2}$	#2
Soybean	splits hand-picked	broken pieces hand-picked	#10	-
Barley	broken kernels cross-sectioned	$\frac{\#8}{\#6}$	-	#6

Note: Sieve numbers shown are those of Carter-Day Dockage tester.

#3 = Broken pieces passing through #3

$\frac{\#3}{\#2}$ = Broken pieces passing through #3 but remaining on #2

$\underline{\#3}$ = Broken pieces remaining on #3

*a = Tyler sieves used (2.00 mm/1.65 mm)

practically applicable to this cleaning test. After these discussions, the definitions of broken and shrunken kernels presented in Table 3 and the composition ratio of impurities in the test grains as shown in Table 4 were used for the remainder of the project.

Accuracy of grain separation operation for each model was evaluated by calculating the

removal efficiency of total impurities.

Precision of grain separation operation for each cleaning equipment was evaluated by computing the coefficient of variation of removal efficiency.

Reproducibility of each model was evaluated by analyzing the difference in performance between the two units, and the difference between the three replicates of test samples.

The evaluation of ease of operation of each model was based on an assessment of ease of feed and air control, changing parts, sieve cleaning, time to test a sample, and noise of the machine during operation.

TABLE 4. Three Impurity Levels of Test Samples.

Low Level

Test Samples / Fractions *	HRW Wheat	Durum	Corn	Soybean	Barley
LM	0.2	0.1	0.3	0.1	0.5
FM	0.4	0.1	0.1	-	0.4
BM#1	2.3	2.7	1.2	3.0	2.2
BM#2	1.0	1.3	2.6	1.8	1.2
BM#3	1.0	0.1	0.7	0.1	-
PM	0.1	0.7	0.1	-	0.7
Total	5%				

Medium Level

Test Samples / Fractions *	HRW Wheat	Durum	Corn	Soybean	Barley
LM	0.4	0.2	0.6	0.2	1.0
FM	0.8	0.2	0.2	-	0.8
BM#1	4.6	5.4	2.4	6.0	4.4
BM#2	2.0	2.6	5.2	3.6	2.4
BM#3	2.0	0.2	1.4	0.2	-
PM	0.2	1.4	0.2	-	1.4
Total	10%				

High Level

Test Samples / Fractions *	HRW Wheat	Durum	Corn	Soybean	Barley
LM	0.6	0.3	0.9	0.3	1.5
FM	1.2	0.3	0.3	-	1.2
BM#1	6.9	8.1	3.6	9.0	6.6
BM#2	3.0	3.9	7.8	5.4	3.6
BM#3	3.0	0.3	2.1	0.3	-
PM	0.3	2.1	0.3	-	2.1
Total	15%				

* LM = Light Materials
FM = Foreign Materials
BM#1 = Broken Kernels, splits or 2/3 intact kernels
BM#2 = Broken and shrunken kernels or 1/3 intact kernels
BM#3 = Fine broken kernels
PM = Powdered particles

EXPERIMENTAL PROCEDURES

A. Adjustment of Air and Feed Control of the Three Grain Cleaning Models

The three cleaning equipment models tested in the project utilize, in principle, air-screen cleaning in which the impurities in grains are separated through aspiration and screening (Figs. 1-5), the screens supplied by the three manufacturers were listed in Table 5. As a result, the settings of air and feed control significantly affect the removal efficiency of each cleaning unit.

It was stated in the Cooperative Agreement (1987) for the project that air and feed control settings of the cleaning units should be made according to the manufacturer's recommendations. The two units of CD-XT3 were examined and adjusted by FGIS, USDA, Kansas City, MO. Additional information on angle adjustment of the trough of the Labofix units was collected. The manufacturer of the N.S.L. units provided operating instructions but had not provided adequate information on the specific settings of the air and feed controls for cleaning of each type of grain, so settings for this model were fixed based on a series of cleaning tests performed in the laboratory. In addition to the recommendations of the three manufacturers for control settings, modifications on settings of aspirators and screens were made, based essentially on the following assumptions in order to evaluate the cleaning efficiencies of each model objectively:

1. Feed control - to be adjusted so that a grain sample of 1 kg passes through all sieves in three minutes or less;
2. Air control - to be adjusted so that not to remove sound kernels from the grain sample;
3. Scalping sieve - the proper sieve that retains only particles larger than whole kernels of the grain being tested; and
4. The 1st Screener - the proper sieve size which can retain all sound kernels of the sample shall be installed. In the case where the indented cylinder or grading cylinder is used, the

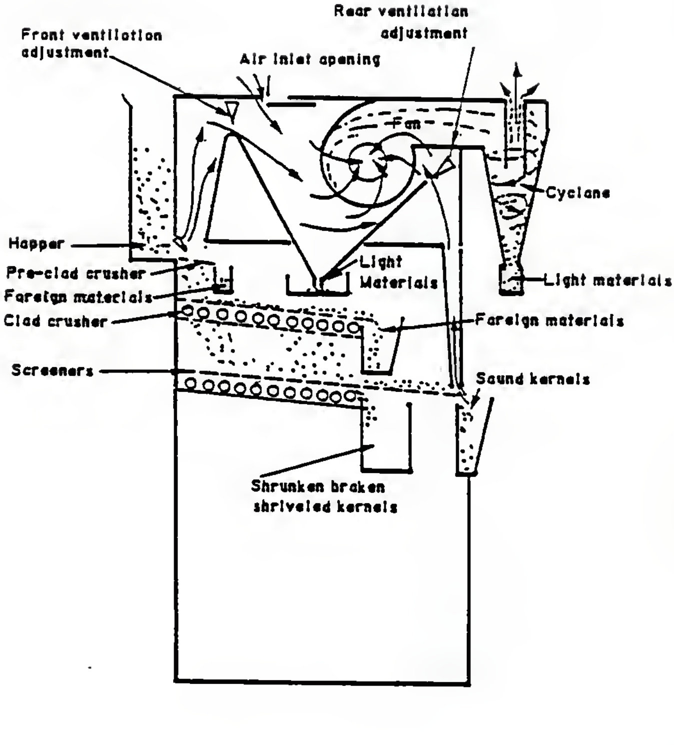
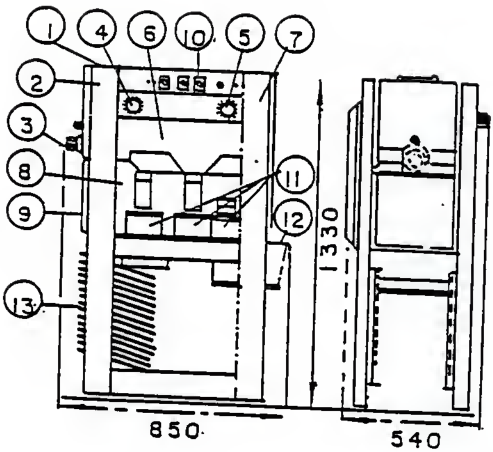


Figure 1. Cross-sectional View of N.S.L. Laboratory Grain Cleaner.



1. Feed hopper
2. Incorporated dehusking
3. Feed output adjustment
4. Front ventilation adjustment
5. Rear ventilation adjustment
6. Fan spar-box
7. Fan filter
8. Screening spar-box
9. Screen access door
10. Control panel
11. Waste recovery
12. Sound grain recovery
13. Perforated steel sheet storage

Figure 2. Schematic Diagram of N.S.L. Laboratory Grain Cleaner.

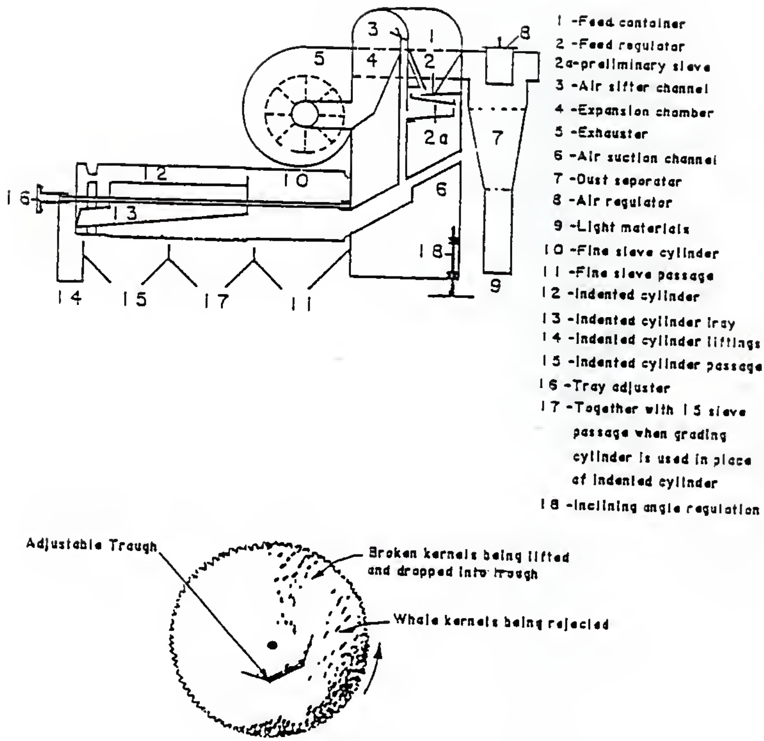


Figure 3. Schematic Diagram of the Labofix grain cleaning unit and Cross-sectional View of Indented Cylinder.

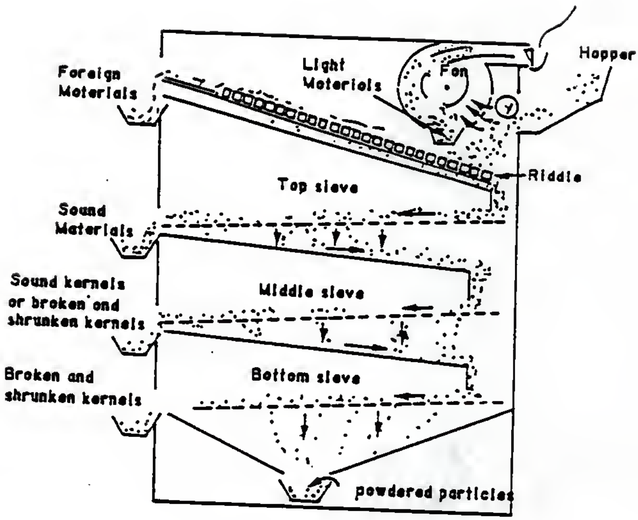
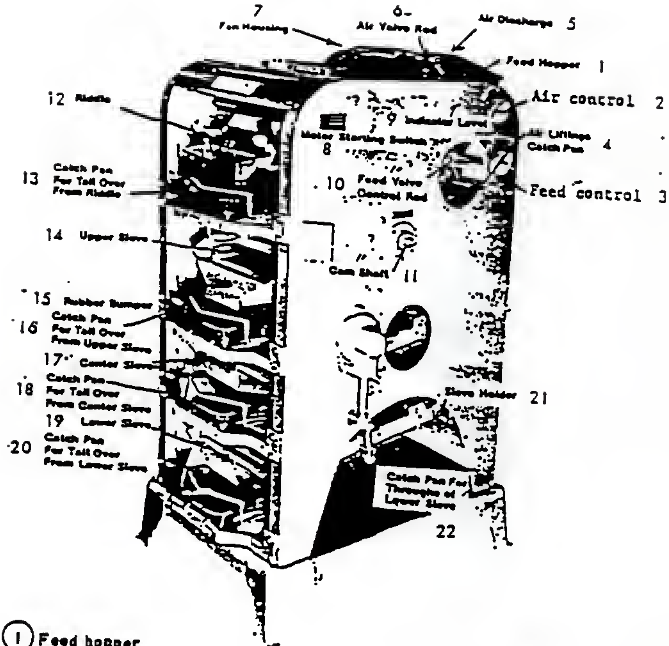


Figure 4. Sectional View of CD-XT3 Dockage Tester.



1. Feed hopper
2. Air control
3. Feed control
4. Air liftings catch pan
5. Air discharge
6. Air valve rod
7. Fan housings
8. Motor starting switch
9. Indicator level
10. Feed valve control rod
11. Cam shaft
12. Riddle
13. Catch pan for tail over from riddle
14. Upper sieve
15. Rubber bumper
16. Catch pan for tail over from upper sieve
17. Center sieve
18. Catch pan for tail over from center sieve
19. Lower sieve
20. Catch pan for tail over from lower sieve
21. Sieve holder
22. Catch pan for thoroughs of lower sieve

Figure 5. Schematic Diagram of CD-XT3 Dockage Tester.

TABLE 5. Screens and Grading Cylinders Supplied by the Three Manufacturers (dimensions: mm)

Model Sieves	CD-XT 3	N.S.L.	Labofix
Scalpers	Riddle No. 000 (5.00) Riddle No. 00 (3.75) Riddle No. 1 (4.33) Riddle No. 2 (5.00) Riddle No. 6 (3.572 x 19.05) Riddle No. 8 (7.90) Riddle No. 25 (5.63)	R 3.0 R 4.5 R 6.0 R 8.0 R 9 R 12 R 14 L 1.5 x 1.5 L 3.5 x 20 L 4.0 x 20 L 4.5 x 20 L 5.0 x 20 L 7.0 x 20	L 3.75 x 20 L 4.0 x 20 L 4.5 x 20 R 3.50 R 4.75 R 5.00 R 5.50 R 9.00 R 12.00
Screens	Sieve No. 1 (R 0.992) R 2.5/64" Sieve No. 2 (R 0.984) R 5/64" Sieve No. 3 (R 4.763) R 12/64" Sieve No. 4 (L 1.626 x 9.525) L 4.125/64" x 3/8" Sieve No. 5 (L 1.778 x 3.969) L 4.5/64" x 3/8" Sieve No. 6 (T 1.984) T 0.078" Sieve No. 7 (R 1.786) R 4.5/64" Sieve No. 8 (T 2.261) T 0.089" Sieve No. 9 L 4.5/64" over R 1/12" Sieve No. 10 (R 3.175) R 8/64" Sieve No. 11 (L 1.270 x 11.91) L 1/20" x 15/32" Sieve No. 12 (L 3.572 x 19.05) L 9/64" x 3/4"	L 1 x 20 L 1.5 x 20 L 1.75 x 20 L 1.8 x 20 L 1.9 x 20 L 2.0 x 20 L 2.1 x 20 L 2.2 x 20 L 2.5 x 20 L 2.8 x 20 L 3.0 x 20 L 3.5 x 20 L 4.0 x 20 L 4.5 x 20 L 5.0 x 20 L 7.0 x 20 R 0.8 R 1.0 R 1.5 R 3.0 R 4.5 R 6.0 R 8.0 R 9.0 R 12.0	**Sieve Cylinder** L 1.25 x 20 L 1.50 x 20 L 1.75 x 20 L 2.00 x 20 L 2.20 x 20 R 2.25 R 5.00 R 6.00 **Indented Cylinder*** 3.0 4.5 6.0 9.5 10.0 11.0 **Grading Cylinder** L 2.20 x 20 L 4.00 x 20 L 4.50 x 20

L = slotted perforated sieve
R = round perforated sieve
T = triangular perforated sieve
* = indentation diameter in mm

size and inclination of cylinder shall be adjusted so that sound kernels of the grain sample will not fall into the broken kernel fraction.

Control settings and sieve selections used for each model and grain type are presented in Table 6 through Tahle 10. These settings and sieve selections were discussed with the manufacturers of the Labofix and N.S.L. models.

B. Preparation of Test Samples

According to the experimental design, each component in the total impurities, namely, light materials, foreign materials, broken and shrunken kernels, and fine materials, was removed from the original grain samples. Sound kernels were considered as the kernels with 1/4 or less removed.

The moisture content of the samples was determined by using the MOTOMCO automatic moisture tester. Most of the grain samples had a low moisture level, since they had heen in the lahoratory for some time, and it was necessary to increase their moisture content to 11% and 15% (W.B.).

The amount of water needed to obtain the desired moisture content was added to clean, sound kernels and the moistened sample was mixed for about 5 minutes using a mixer. The sample was then left in a cold chamher (maintained at 8 to 10 C) for four days, and turned over at least once a day for equilibrium to he established. For 15% moisture content samples, the hroken materials were also wetted so that they would not be too dry as compared with the 15% M.C. sound kernels.

After conditioning, the test samples were prepared hy adding 50 g, 100 g, or 150 g of impurities to the sound kernel fraction of 950 g, 900 g, or 850 g, respectively, to make a 1-kg size test sample.

TABLE 6. The Setting of Aspirators and Screens for the Three Laboratory Grain Cleaners when Testing HRW Wheat

	CD XT-3		N.S.L.		Labofix	
	Specification	Dimension (mm)	Specification	Dimension (mm)	Specification	Dimension (mm)
Feed & Air Control	Single Aspiration F.C.: 6 A.C.: 4		Double Aspiration F.C.:2 A.C.:6 (Front), AIO:4	6 (Rear)	Single Aspiration F.C.: 1.2 A.C.: 4.5 A.T.: 3 Incl.: Horizontal	
Scalping Sieves	Riddle #2	5.0 x 5.0	Pre-clod Crusher	RH 9.0	Pre-sieve	LH 4.0 x 22
			Clod Crusher	LH 3.50 x 20		
1st Screening			Screener	LH 1.75 x 20	Fine Sieve Cylinder	LH 1.75 x 20
2nd Screening	Middle Sieve #2	RH 1.98			Indented Cylinder	4.5
					Grading Cylinder	
3rd Screening	Bottom Sieve #2	RH 1.98				

AIO = Air inlet opening
F.C. = Feed control
A.C. = Air control
A.T. = Angle of trough
Incl. = Inclination

LH = Slotted perforated sieve
RH = Round perforated sieve

TABLE 7. The Setting of Aspirators and Screens for the Three Laboratory Grain Cleaners when Testing Durum

	CD XT-3		N.S.L.		Labofix	
	Specification	Dimension (mm)	Specification	Dimension (mm)	Specification	Dimension (mm)
Feed & Air Control	Single Aspiration F.C.: 6 A.C.: 4		Double Aspiration F.C.:3 A.C.: 5 (Front), AIO:4	4 (Rear)	Single Aspiration F.C.: 1.2 A.C.: 4.5 A.T.: 5 Incl.: Horizontal	
Scalping Sieves	Riddle #25	5.63 x 5.63	Pre-clod Crusher	RH 9.0	Pre-sieve	LH 4.5 x 22
			Clod Crusher	LH 4.5 x 20		
1st Screening			Screener	LH 1.75 x 20	Fine Sieve Cylinder	LH 1.75 x 20
2nd Screening	Middle Sieve #2	RH 1.98			Indented Cylinder	4.5
					Grading Cylinder	
3rd Screening	Bottom Sieve #2	RH 1.98				

AIO = Air inlet opening
F.C. = Feed control
A.C. = Air control
A.T. = Angle of trough
Incl. = Inclination

LH = Slot. perforated sieve
RH = Round perforated sieve

TABLE 8. The Setting of Aspirators and Screens for the Three Laboratory Grain Cleaners when Testing Barley

	CD XT-3		N.S.L.		Labofix	
	Specification	Dimension (mm)	Specification	Dimension (mm)	Specification	Dimension (mm)
Feed & Air Control	Single Aspiration F.C.: 6 A.C.: 4		Double Aspiration F.C.: 3 A.C.: 5 (Front), AIO: 4	5 (Rear)	Single Aspiration F.C.: 1.5 A.C.: 3.6 A.T.: 3 Incl.: Horizontal	
Scalping Sieves	Riddle #6	3.57 x 3.57	Pre-clod Crusher	RH 9.0	Pre-sieve	LH 4.5 x 22
			Clod Crusher	LH 4.0 x 20		
1st Screening	Top Sieve #8	Tri 2.26	Screener	LH 2.0 x 20	Fine Sieve Cylinder	LH 2.0 x 25
2nd Screening	Middle Sieve #6	Tri 1.98			Indented Cylinder	6.0
					Grading Cylinder	
3rd Screening						

AIO = Air inlet opening
F.C. = Feed control
A.C. = Air control
A.T. = Angle of trough
Incl. = Inclination

LH = Slotted perforated sieve
RH = Round perforated sieve
Tri. = Triangular perforated sieve

TABLE 9. The Setting of Aspirators and Screens for the Three Laboratory Grain Cleaners when Testing Corn

	CD XT-3		N.S.L.		Labofix	
	Specification	Dimension (mm)	Specification	Dimension (mm)	Specification	Dimension (mm)
Feed & Air Control	Single Aspiration F.C.: 10 A.C.: 1		Double Aspiration F.C.:4 A.C.:6 (Front), AIO: 4	2 (Rear)	Single Aspiration F.C.: 2.2 A.C.: 5.0 A.T.: 3 Incl.: Horizontal	
Scalping Sieves			Pre-clod Crusher	RH 14.0	Pre-sieve	RH 12.0
			Clod Crusher	RH 12.0		
1st Screening	Top Sieve #3	RH 4.76	Screener	RH 4.5	Fine Sieve Cylinder	RH 5.0
2nd Screening					Indented Cylinder	9.5
					Grading Cylinder	
3rd Screening						

AIO = Air inlet opening
F.C. = Feed control
A.C. = Air control
A.T. = Angle of trough
Incl. = Inclination

LH = Slotted perforated sieve
RH = Round perforated sieve

TABLE 10. The Setting of Aspirators and Screens for the Three Laboratory Grain Cleaners when Testing Soybean

	CD XT-3		N.S.L.		Labofix	
	Specification	Dimension (mm)	Specification	Dimension (mm)	Specification	Dimension (mm)
Feed & Air Control	Single Aspiration F.C.: 6.0-10.0 A.C.: 4.0		Double Aspiration F.C.: 4 A.C.: 6 (Front), AIO: 3	4 (Rear)	Single Aspiration F.C.: 2.0 A.C.: 5.0 A.T.: Incl. = Uphill	
Scalping Sieves			Pre-clod Crusher	RH 12.0	Pre-sieve	RH 9.0
			Clod Crusher	RH 9.0		
1st Screening	Top Sieve #10	RH 3.18	Screener	LH 4.0 x 20	Fine Sieve Cylinder	R 5.0
2nd Screening					Indented Cylinder	
					Grading Cylinder	LH 4.0 x 25
3rd Screening						

AIO = Air inlet opening
F.C. = Feed control
A.C. = Air control
A.T. = Angle of trough
Incl. = Inclination

LH = Slotted perforated sieve
RH = Round perforated sieve

C. Tests

As indicated in the experimental design, 5 parameters were investigated:

(3-model)×(2-unit)×(3-impurity)×(2-moisture)×(3-replicate)

Therefore, 108 test samples were prepared for each crop, and a total of 540 tests for five crops were conducted for the research project.

For each test, different fractions were collected, weighted on electronic balances, and recorded on the test data sheet shown in Table 11 as light materials, foreign materials, broken and shrunken materials, fine materials, and sound kernels. In addition, testing time and noise level were recorded. Air and feed control, sieve-self cleaning and ease of changing parts were ranked by numbers for evaluating ease of operation for the three models.

Since the Carter-Day Dockage tester has not been officially recognized as a separating machine for broken and shrunken kernels of wheat, further tests on broken and shrunken kernel separation were conducted by using a slotted hole sieve (L1.626 × 9.525 mm, or 4.125/64" × 3/8", #4) on an official mechanical sieve shaker approved by FGIS, with about one-fourth of the sound kernel fraction sample rejected by the #2 sieve on the CD-XT3 model. The data were analyzed for improving the removal efficiency for this model.

In addition to the two classes of wheat, the tests were conducted also with barley samples for further separation by a mechanical sieve shaker.

TABLE 11. Test Data Sheet

No.________

Operator:________________ Machine:________________

Date:________________

Test Sample: ____1 Kg Type of Grains:____________

M.C. level: __________ Feed Control:____________

Impurity level: ________ Air Control:____________

No. of Replicates / Fractions*		1	2	3
S1B				
S2B				
S3B				
S4B				
S5B				
S6B				
Mechanical Sieve	SM			
	BM			
Testing time[1]				
Feed control[2]				
Air control[3]				
Sieve Cleaning[4]				
Comment				

*Fractions

	CD XT-3	N.S.L.	Labofix**
S1B	LM	LM#1	LM
S2B	FM	FM#1	FM
S3B	SM	FM#2	BM#2
S4B	BM#1 or SM	SM	SM (BM)
S5B	BM#2	BM	BM#1 (BM)
S6B	PM	LM#2	- (SM)

**Indented cylinder installed

( ): Grading cylinder installed

[1] Testing time was measured in minutes used to clean the grain sample of 1 kg.

[2] Feed control with weighted factors: excellent=3; good=2; fair=1.

[3] Air control with weighted factors: excellent=3; good=2; fair=1.

[4] Sieve cleaning with weighted factors: excellent=3; good=2; fair=1.

D. Preparation of Additional Test Samples for Official Grading

In order to compare the test results to the results of official grading, one duplicate set of each impurity level and moisture content for the five crops used in the project was prepared, and these 30 test samples were then sent to the Kansas State Grain Inspection Service (KSGIS), Topeka, Kansas. And, the results from the two different separating procedures were compared and analyzed.

RESULTS AND DISCUSSION

It should be noted first that the removal efficiencies for light materials and broken materials were adjusted for analyses. The removal efficiency for light materials was higher than 100% for the N.S.L. and Labofix models because these two models removed more materials, which included some of the brokens and fine materials in the light material fraction. It was assumed that removal efficiency for light materials was 100% for these tests. The extra amount of materials was added to broken and fine materials fraction so that the removal efficiency for broken materials was improved. The original data of light materials and broken materials removed were shown in Tables A.I through A.V in the Appendix.

For example, assume that the input was 5 g of light materials and 40 g broken and fine materials. If the output of light materials was 10 g, and broken and fine materials was 20 g, the removal efficiency was calculated as 200% for light materials, and 50% for broken materials. The adjustment for these two numbers were: 100% for light materials, and 62.5% for broken materials. However, the overall removal efficiency remained the same after adjustment.

In this section, first, the results and discussion of removal efficiencies, accuracy, precision, reproducibility, and mechanical sieve shaker tests (in reference to Carter-Day Dockage tester) are presented for each crop. After crop by crop presentation on the above matters, applicability, ease of operation, and comparison between the results by Kansas State Grain Inspection Service and the laboratory tests are discussed by considering all five crops tested.

I. Analysis of Removal Efficiency and Some Evaluations by Each Crop

A. Hard Red Winter Wheat

1. Removal efficiency

The results of average overall removal efficiencies are presented graphically in Figures 6a and 6b. Also, Tables A.1a through A.6a in the Appendix contain the calculated values of overall efficiency for the three replicates at impurity levels of 5%, 10%, and 15%, with moisture contents of 11% and 15% for the three models of cleaning machines tested.

The average overall removal efficiency of the three models for hard red winter wheat was found to be in the following order:

Labofix > N.S.L. > CD-XT3

The ranges of average overall efficiency were from 9.9% to 13.3% for CD-XT3, from 18.0% to 46.9% for N.S.L., and from 69.7% to 94.0% for Labofix.

The statistical analysis showed that the difference between the three models was significant.

The removal efficiencies of light materials, foreign materials, and broken materials are presented in Figures A.1 through A.6 in the Appendix. These values are also presented in Tables A.1b through A.6b in the Appendix. The average removal efficiency of each component of impurities was found to be in the following order:

η_L for light materials:	N.S.L. $\simeq$ Labofix > CD-XT3
η_F for foreign materials:	CD-XT3 > Labofix $\simeq$ N.S.L.
η_B for broken materials:	Labofix > N.S.L. > CD-XT3

For overall efficiency, the statistical analysis showed that the effect of moisture content was significant for the CD-XT3 model and unit 1 of the Labofix model (Table A.31); the effect of impurity level was not significant except for unit 2 of N.S.L. model

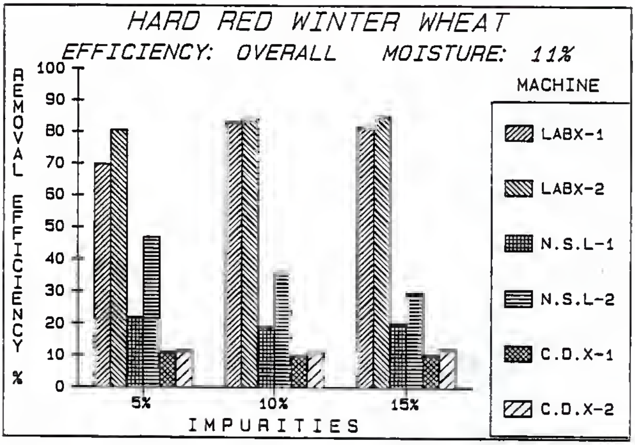


Figure 6a. Overall Removal Efficiency by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Hard Red Winter Wheat at 11% Moisture.

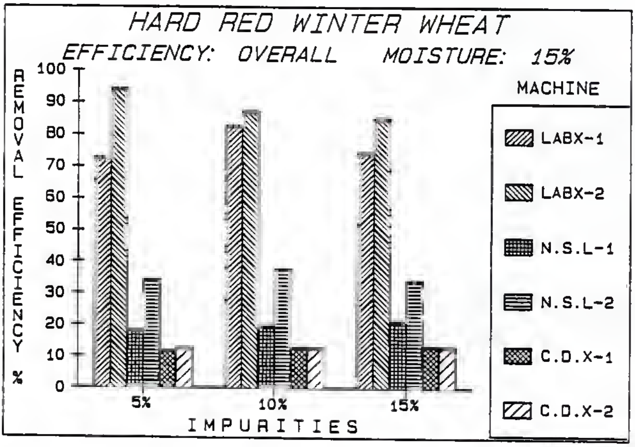


Figure 6b. Overall Removal Efficiency by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Hard Red Winter Wheat at 15% Moisture.

(Table A.32); the difference between the two units of N.S.L. and CD-XT3 models was not significant, but it was significant for Labofix model (Table A.33); the three replicates were not significantly different (Table A.34).

For removal efficiency of light materials, the moisture effect could be ignored for Labofix and N.S.L. models after the data adjustment because all the values of removal efficiency for light materials were 100%. For the CD-XT3 model, the effect of moisture content was significant (Table A.35); the effect of impurity level was significant for unit 2 (Table A.36); the difference between the two units was significant (Table A.37); and the three replicates were not significantly different (Table A.38).

For removal efficiency of foreign materials, the effect of moisture content was significant for the CD-XT3 model, but not for Labofix and N.S.L. models (Table A.39); the effect of impurity level was not significant for any of the three models (Table A.40); the difference between the two units was not significant (Table A.41); and there was no significant differences between the three replicates (Table A.42).

For removal efficiency of broken materials, the effect of moisture content and impurity level were not significant except for unit 1 of the Labofix model (Tables A.43 and A.44); the difference between the two units was significant for Labofix and N.S.L. models, but not for CD-XT3 model (Table A.45); there was no significant difference between the three models (Table A.46).

A summary table for hard red winter wheat showing means, standard deviations and ranges of overall efficiency, and removal efficiencies of light materials, foreign materials, and broken kernels for the three models tested is presented in Table A.47 in the Appendix.

2. Evaluation of Accuracy, Precision, and Reproducibility

Based on the overall removal efficiency, accuracy of each model was found to be the following order:

Labofix > N.S.L. > CD-XT3

Based on the coefficient of variance, precision of each model was found to be the following order:

Labofix > CD-XT3 > N.S.L.

and the results on average coefficient of variance are shown in the following table:

TABLE 12. The Average Values of Coefficient of Variance for HRW Wheat.

Unit	Labofix	N.S.L.	CD-XT3
1	9.02%	10.14%	11.92%
2	7.04%	17.72%	8.13%

The difference between the two units of Labofix and N.S.L. on overall removal efficiency was statistically significant; there was no significant difference between the three replicates for any of the models. Therefore, the reproducibility was found to be in the following order:

CD-XT3 > Labofix = N.S.L.

3. Tests by Mechanical Sieve Shaker

About one-fourth of the sound kernel fraction rejected by the #2 sieve from a test with the CD-XT3 model was further sieved by using a U.S. standard sieve (L1.626 × 9.525 mm, or 4.125/64" × 3/8") on an official mechanical sieve shaker approved by the FGIS. The results of broken/sound kernel fractions separated are presented in Tables A.52 in the Appendix.

The broken fraction separated by the mechanical shaker was weighted about 40% of the total impurities. Therefore, the additional tests showed that the overall efficiency of CD-XT3 for HRW wheat could be increased if the proper sieve was used. The projected increase at different moisture contents and impurity levels for CD-XT3 are presented in the following table:

TABLE 13. The Results on the Projected Increase of Overall Removal Efficiency at Different Moisture Contents and Impurity Levels for HRW Wheat.

Moisture content	Impurity level		
	5%	10%	15%
11%	41.3%	42.9%	41.5%
15%	40.2%	40.2%	39.0%

B. Durum Wheat

1. Removal efficiency

The results of average overall removal efficiencies are presented graphically in Figures 7a and 7b. Also, Table A.7a through Table A.12a in the Appendix contain the calculated values of overall removal efficiencies for the three replicates at impurity levels of 5%, 10%, and 15%, with moisture contents of 11% and 15% for the three models of cleaning machines tested.

The average overall removal efficiency of the three models for durum wheat was found to be in the following order:

Labofix > N.S.L. > CD-XT3

The ranges of average overall removal efficiencies for the three models tested were from 17.3% to 17.9% for CD-XT3, from 19.2% to 23.2% for N.S.L., and from 56.8% to 85.1% for Labofix.

The statistical analysis showed that the difference between the three models was significant.

The removal efficiencies of light materials, foreign materials, and broken materials are presented in Figures A.7 through A.12 in the Appendix. These values are also presented in Table A.7b through Table A.12b in the Appendix. The average removal efficiency of each component of impurities was found to be in the following order:

η_L for light materials:	N.S.L. = Labofix > CD-XT3
η_F for foreign materials:	CD-XT3 > Labofix $\simeq$ N.S.L.
η_B for broken materials:	Labofix > N.S.L. > CD-XT3

For overall removal efficiency, the statistical analysis showed that the effect of moisture content was significant except for unit 1 of N.S.L. model (Table A.31); the effect

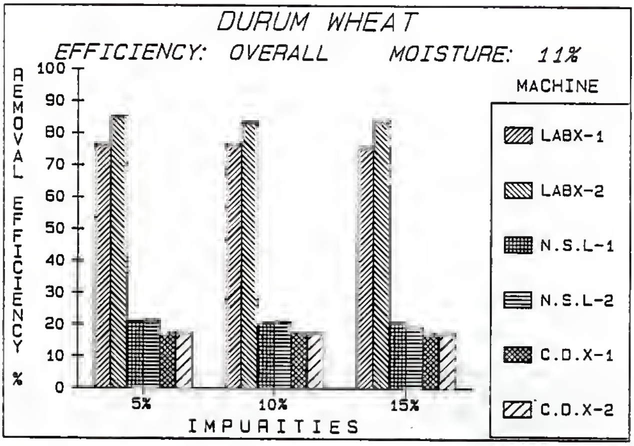


Figure 7a. Overall Removal Efficiency by Two Units Each of Labofix, N.S.L.,and CD-XT3 Models for Durum Wheat at 11% Moisture.

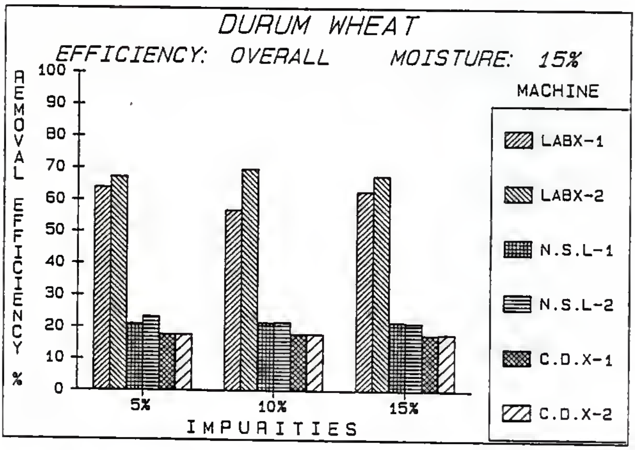


Figure 7b. Overall Removal Efficiency by Two Units Each of Labofix, N.S.L.,and CD-XT3 Models for Durum Wheat at 15% Moisture.

of impurity level was not significant for all the models except unit 2 of N.S.L. model (Table A.32); the difference between the two units was significant for Labofix model, but not for N.S.L. and CD-XT3 models (Table A.33); the three replicates were not significantly different for any of the models (Table A.34).

For removal efficiency of light materials, there was no moisture effect for N.S.L. and Labofix models after the adjustment. For the CD-XT3 model, the effect of moisture content was statistically significant (Table A.35); the effect of impurity level was significant for unit 1 (Table A.36); the difference between the two units was significant (Table A.37); the three replicates were not significantly different (Table A.38).

For removal efficiency of foreign materials, the effect of moisture content was not significant(Table A.39); the effect of impurity level was significant only for unit 1 of N.S.L. and CD-XT3 models (Table A.40); the difference between the two units was not significant for any of the three models (Table A.41); and the three replicates were not significantly different except for unit 2 of the CD-XT3 model (Table A.42).

For removal efficiency of broken materials, the effect of moisture content was statistically significant (Table A.43); the effect of impurity level was not significant (Table A.44); the difference between the two units was significant for the Labofix model, but not for N.S.L. and CD-XT3 models (Table A.45); and the three replicates were not significantly different for any of the models (Table A.46).

A summary table for durum wheat showing means, standard deviations and ranges of overall efficiency, and removal efficiencies of light materials, foreign materials, and broken kernels for the three models tested is presented in Table A.48 in the Appendix.

2. Evaluation of Accuracy, Precision, and Reproducibility

Based on removing efficiency, the accuracy was found to be in the following order:

Labofix > N.S.L. > CD-XT3

Based on the coefficient of variance, the precision was found to be in the following order:

CD-XT3 > N.S.L. > Labofix

and the results for average coefficient of variance are shown in the following table:

TABLE 14. The Average Values of Coefficient of Variance for Durum Wheat.

Unit	Labofix	N.S.L.	CD-XT3
1	12.49%	3.04%	1.42%
2	11.54%	6.03%	1.53%

The difference between the two units of CD-XT3 and N.S.L. models on overall removal efficiency was not statistically significant; and the there was no significant difference between three replicates for any of the three models. Therefore, the reproducibility was found to be in the following order:

CD-XT3 = N.S.L. > Labofix

3. Tests by Mechanical Sieve Shaker

About one-fourth of the sound kernel fraction from a test with the CD-XT3 which remained on #2 sieve was further sieved using U.S.standard sieve (L1.626 × 9.525 mm, or 4.125/64" × 3/8") on an official mechanical sieve shaker approved by the FGIS. The results of broken/sound kernel fraction separated are presented in Table A.53 in the Appendix.

The fraction remaining on the sieve was called the sound fraction, and those that

passing through the sieve was broken materials, which weighted about 20% of the total impurities. Therefore, the additional tests showed that the separating efficiency of CD-XT3 could be increased if the #4 sieve was used. The projected increases at different moisture contents and impurity levels for the CD-XT3 are presented in the following table:

TABLE 15. The Results on the Projected Increase of Overall Removal Efficiency at Different Moisture Contents and Impurity Levels for Durum Wheat.

Moisture content	Impurity level		
	5%	10%	15%
11%	20.4%	20.1%	21.5%
15%	19.2%	19.0%	19.7%

C. Barley (six-row)

1. Removal efficiency

The results of average overall removal efficiencies are presented graphically in Figures 8a and 8b. Also, Table A.13a through Table A.18a in the Appendix contain the calculated values of overall efficiencies for the three replicates at impurity levels of 5%, 10%, and 15%, with moisture contents of 11%, and 15% for the three models of cleaning machines tested.

The average overall removal efficiency of the three models for barley was found to be in the following order:

Labofix > CD-XT3 > N.S.L.

The ranges of average overall efficiencies were from 28.2% to 34.1% for N.S.L., from 33.5% to 38.7% for CD-XT3, and from 84.9% to 92.8% for Labofix.

The statistical analysis showed that the difference between the three models was significant.

The removal efficiencies of light materials, foreign materials, and broken materials are presented in Figures A.13 through A.18 in the Appendix. These values are also presented in Table A.13b through A.18b in the Appendix. The average removal efficiency of each component of impurities was found to be in the following order:

η_L for light materials: N.S.L. = Labofix > CD-XT3
η_F for foreign materials: CD-XT3 = N.S.L. > Labofix
η_B for broken materials: Labofix > CD-XT3 > N.S.L.

For overall efficiency, the statistical analysis showed that the effect of moisture content was significant for the N.S.L. model, unit 1 of the CD-XT3 model, and unit 2 of the Labofix model (Table A.31); the effect of impurity level was significant for Labofix model,

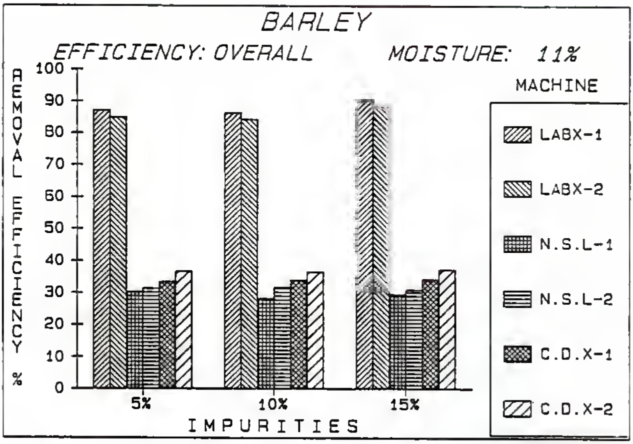


Figure 8a. Overall Removal Efficiency by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Barley at 11% Moisture.

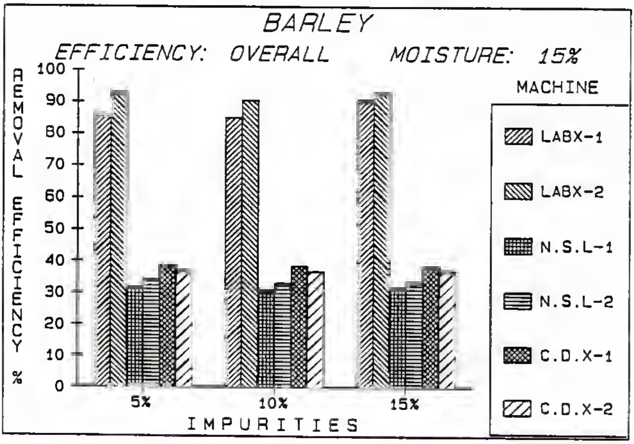


Figure 8b. Overall Removal Efficiency by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Barley at 15% Moisture.

but not for N.S.L. and CD-XT3 models (Table A.32); the difference between the two units was significant for all the three models (Table A.33); the three replicates were not significantly different except for unit 2 of the Labofix model (Table A.34).

For removal efficiency of light materials, there was no moisture effect for Labofix and N.S.L. models. For the CD-XT3 model, the effect of moisture content was significant (Table A.35); the effect of impurity level was not significant (Table A.36); the difference between the two units was significant (Table A.37); and the three replicates were not significantly different (Table A.38).

For removal efficiency of foreign materials, the effect of moisture content was significant for all three models (Table A.39); the effect of impurity level was not significant except for the unit 2 of the Labofix model (Table A.40); the difference between the two units was significant for all the three models (Table A.41); and the three replicates were not significantly different (Table A.42).

For removal efficiency of broken materials, the effect of moisture content was significant except for unit 1 of the Labofix model (Table A.43); the effect of impurity level was not significant except for unit 1 of the Labofix model (Table A.44); the difference between the two units was significant for Labofix and N.S.L. models, but it was not for the CD-XT3 model (Table A.45); and the three replicates were not significantly different except for unit 2 of N.S.L. model (Table A.46).

A summary table for barley showing means, standard deviations and ranges of overall efficiency, and removal efficiencies of light materials, foreign materials, and broken kernels for the three models tested is presented in Table A.49 in the Appendix.

2. Evaluation of Accuracy, Precision, and Reproducibility

Based on overall efficiency , accuracy of each model was found to be in the following order:

Labofix > CD-XT3 > N.S.L.

Based on the values of coefficient of variance, precision was found to be in the following order:

Labofix > CD-XT3 > N.S.L.

and the results for average coefficient of variance are shown in the following table:

TABLE 16. The Average Values of Coefficient of Variance for Barley.

Unit	Labofix	N.S.L.	CD-XT3
1	2.79%	4.91%	6.82%
2	4.14%	4.53%	1.76%

The difference between the two units of all three models on overall removal efficiency was statistically significant, and there was no significant difference between the three replicates except for unit 2 of Labofix model. Therefore, reproducibility of each model was found to be in the following order:

N.S.L. = CD-XT3 > Labofix

3. Tests by Mechanical Sieve Shaker

The barley samples were also further separated by the mechanical sieve shaker. About one-fourth of the sound kernel fraction sample from a test with the CD-XT3 which was rejected by the #8 sieve was further sieved using a designated sieve (1.984 × 19.05 mm, or 5/64" × 3/4") on an official mechanical sieve shaker approved by FGIS. The results of broken/sound kernel fractions separated are presented in Tables A.54 in the Appendix.

The broken material fraction was weighted about 30% of the total impurities. Therefore, it can be concluded from the additional tests that the overall efficiency of the CD-XT3 model for barley could be increased if the sieve (1.984 × 19.05 mm, or 5/64" × 3/4") was used. The projected increase at different moisture content and impurity level are presented in the following table:

TABLE 17. The Results on the Projected Increase of Overall Removal Efficiency at Different Moisture Contents and Impurity Levels for Barley.

Moisture content	Impurity level		
	5%	10%	15%
11%	30.5%	27.6%	25.8%
15%	41.0%	29.0%	25.9%

D. Yellow Dent Corn

1. Removal efficiency

The results of average overall removal efficiencies are presented graphically in Figures 9a and 9b. Also, Table A.19a through Table A.24a in the Appendix contain the calculated values of overall efficiency for the three replicates at impurity levels of 5%, 10%, and 15%, with moisture contents of 11% and 15% for the three models of cleaning machines tested.

The average overall removal efficiency of the three models for corn was found to be in the following order:

Labofix > CD-XT3 > N.S.L.

The ranges of average overall efficiency were from 13.7% to 16.0% for N.S.L., from 20.5% to 25.1% for CD-XT3, and from 35.7% to 46.8% for Labofix.

The statistical analysis showed that the difference between the three models was significant.

The removal efficiencies of light materials, foreign materials, and broken materials are presented in Figures A.19 through A.22 in the Appendix. These values are also presented in Table A.19b through Table A.24b in the Appendix. The average removal efficiency of each component of impurities was found to be in the following order:

η_L for light materials: N.S.L. = Labofix > CD-XT3
η_B for broken materials: Labofix > CD-XT3 > N.S.L.

It should be noted that the foreign materials for corn samples are defined as other smaller grains, such as grain sorghum, which could not be separated by the scalper. Most of these materials were separated by screens together with broken kernels and were weighted as broken fraction.

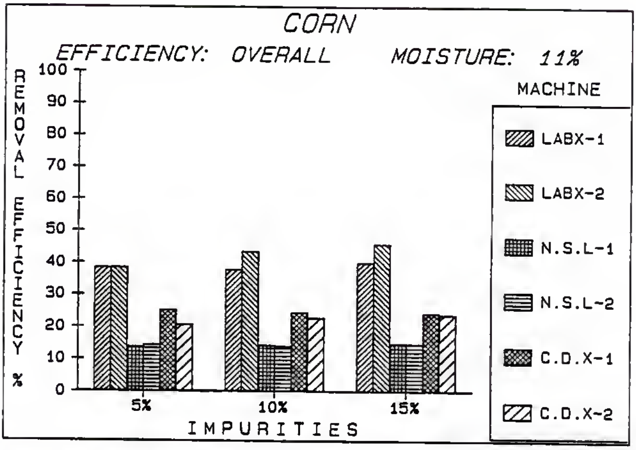


Figure 9a. Overall Removal Efficiency by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Yellow Dent Corn at 11% Moisture.

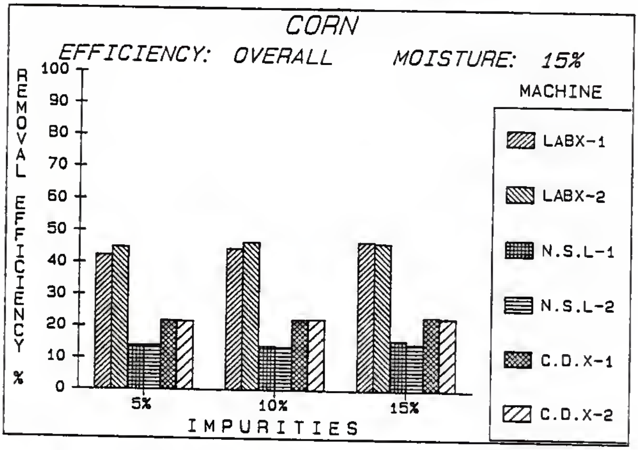


Figure 9b. Overall Removal Efficiency by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Yellow Dent Corn at 15% Moisture.

For overall removal efficiency, the statistical analysis showed that the effect of moisture content was significant for the Labofix model, and unit 1 of the CD-XT3 model (Table A.31); the effect of impurity level was significant only for unit 2 of Labofix and CD-XT3 models (Table A.32); the difference between the two units was significant for Labofix and CD-XT3 models, but not for the N.S.L. model (Table A.33); and there was no significant differences between the three replicates except for unit 2 of the CD-XT3 model (Table A.34).

The removal efficiency of light materials appeared to be zero with the CD-XT3 model because it is officially designed for separating corn without turning the aspiration on. And, all the effects on the removal efficiency of light materials were not significant for Labofix and N.S.L. models.

For removal efficiency of broken materials, the effect of moisture content was significant for the Labofix model and unit 1 of the CD-XT3 model (Table A.43); the effect of impurity level was significant only for unit 2 of Labofix and CD-XT3 models (Table A.44); the difference between the two units was significant for Labofix and CD-XT3 models, but not for the N.S.L. model (Table A.45); and there was no significant differences between the three replicates except for unit 2 of the CD-XT3 model (Table A.46).

A summary table for yellow corn showing means, standard deviations and ranges of overall efficiency, and removal efficiencies of light materials, and broken kernels for the three models tested is presented in Table A.50 in the Appendix.

2. Evaluation of Accuracy, Precision, and Reproducibility

Based on overall removal efficiency, accuracy of each model was found to be in the following order:

Labofix > CD-XT3 > N.S.L.

Based on the coefficient of variance, precision of each model was found to be in the following order:

CD-XT3 > N.S.L. > Labofix

and the results for average coefficient of variance are shown in the following table:

TABLE 18. The Average Values of Coefficient Variance for Yellow Dent Corn.

Unit	Labofix	N.S.L.	CD-XT3
1	8.68%	8.33%	5.26%
2	7.12%	5.14%	4.96%

The difference between the two units of Labofix and CD-XT3 models on overall efficiency was statistically significant, and there was no significant difference between the three replicates except for unit 2 of the CD-XT3 model. Therefore, reproducibility was found to be in the following order:

N.S.L. > Labofix > CD-XT3

3. Separation with Double Sieve on the CD-XT3 Model

The purpose of using double sieve was to separate the components of BCFM (broken materials and foreign materials) with precision. The top sieve on the double sieve was the #3 sieve which was the only one sieve used for corn in this project, and the bottom one was a round hole sieve (2.381 mm, or 6/64"). Since the definition of "foreign materials" by the FGIS was different from the one used in this project, it is hard to see the difference on the precision. And, the removal efficiency was about the same because the double sieve only divided the broken material fraction to two parts by the 2.381 mm (6/64")

sieve.

The results of removal efficiency for broken materials and total impurity at moisture content 11% are presented in the following table:

TABLE 19. Removal Efficiency of CD-XT3 Model with a Double Sieve for Yellow Dent Corn at 11% Moisture Content.

I.M. / Efficiency of	5%	10%	15%
Broken	26.61%	25.85%	25.37%
Total	24.48%	23.78%	23.90%

It might be suggested that since the double sieve installation was complicated, it would be a simple to use two single sieves, and the results would be same.

E. Soybeans

1. Removal efficiency

The results of average overall removal efficiencies are presented graphically in Figures 10a and 10b. Also, Table A.25a through A.30a in the Appendix contain the calculated values of overall efficiencies for the three replicates at impurity levels of 5%, 10%, and 15%, with moisture contents of 11% and 15% for the three models of cleaning machines tested.

The average overall removal efficiency of the three models for soybeans was found to be in the following order:

Labofix > N.S.L. > CD-XT3

The ranges of average overall efficiencies were from 3.7% to 4.1% for CD-XT3, from 53.0% to 62.6% for N.S.L., and 98.5% or higher for Labofix.

The statistical analysis showed that the difference between the three models was significant.

The removal efficiencies of light materials, foreign materials, and broken materials are presented in Figures A.23 through A.26 in the Appendix. These values are also presented in Table A.25b through A.30b in the Appendix. The average removal efficiency of each component of impurities was found to be in the following order:

η_L for light materials: N.S.L. $\simeq$ Labofix > CD-XT3
η_B for broken materials: Labofix > N.S.L. > CD-XT3

The removal efficiency for foreign materials appeared to be zero because there was nothing added as foreign materials to the test samples, which would be the normal soybeans being dealt with.

For overall removal efficiency, the effect of moisture content was significant for the

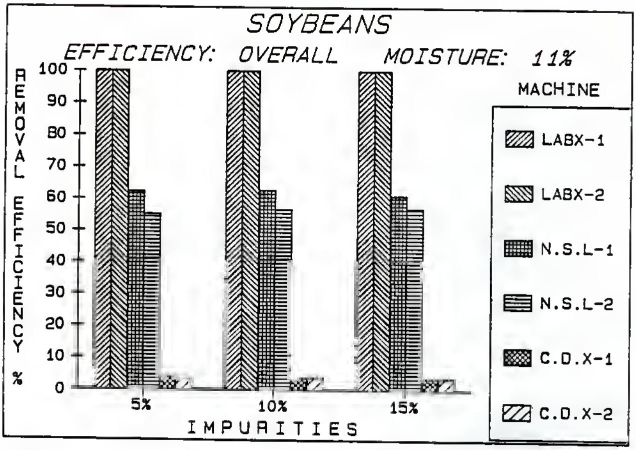


Figure 10a. Overall Removal Efficiency by Two Units Each of Labofix, N.S.L.,and CD-XT3 Models for Soybeans at 11% Moisture.

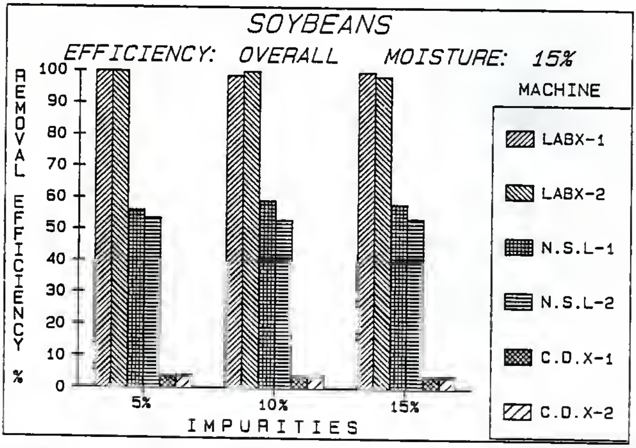


Figure 10b. Overall Removal Efficiency by Two Units Each of Labofix, N.S.L.,and CD-XT3 Models for Soybeans at 15% Moisture.

N.S.L. model, and unit 2 of Labofix and CD-XT3 models (Table A.31); the effect of impurity level was not significant for any of the three models (Table A.32); the difference between the two units was significant for the N.S.L. model, but not for Labofix and CD-XT3 models (Table A.33); and there was no significant differences between the three replicates (Table A.34).

For removal efficiency of light materials, all the effects were not significant for Labofix and N.S.L. models. For the CD-XT3 model, the effect of moisture content was significant (Table A.35); the effect of impurity level was not significant (Table A.36); the difference between the two units was significant (Table A.37); and there was no significant differences between the three replicates (Table A.38).

For removal efficiency of broken materials, the effect of moisture content was significant except for unit 1 of the Labofix model (Table A.43); the effect of impurity level was not significant except for unit 1 of the CD-XT3 model (Table A.44); the difference between the two units was significant for the N.S.L. model, but not for Labofix and CD-XT3 models (Table A.45); there was no significant differences between the three replicates except for unit 1 of the CD-XT3 model (Table A.46).

A summary table for soybeans showing means, standard deviations and ranges of overall efficiency, and removal efficiencies of light materials, and broken kernels for the three models tested is presented in Table A.51 in the Appendix.

2. Evaluation of Accuracy, Precision, and Reproducibility

Based on overall efficiency, accuracy of each model was found to be in the following order:

Labofix > N.S.L. > CD-XT3

Based on the coefficient of variance of removal efficiency, precision was found to be

in the following order:

Labofix > N.S.L. > CD-XT3

and the results for average coefficient of variance of each unit are shown in the following table:

TABLE 20. The Average Values of Coefficient of Variance for Soybeans.

Unit	Labofix	N.S.L.	CD-XT3
1	1.53%	4.69%	3.99%
2	1.33%	3.47%	5.54%

The difference between the two units of Labofix and CD-XT3 models was not statistically significant, and there was no significant differences among the three replicates for any of the three models. Therefore, reproducibility of each model was found to be in the following order:

Labofix = CD-XT3 > N.S.L.

II. Applicability to Five Crops

The ranges and average values of overall removal efficiencies are summarized in Table 21 and Table 22. The ranges of average values for the five crops tested were from 35.4% to 106.0% for the Labofix model, from 12.8% to 64.6% for the N.S.L. model, and from 3.5% to 39.4% for the CD-XT3 model.

The statistical analysis showed that the means of overall removal efficiency for each of the five crop tested were significantly different each other.

The results showed that no model tested is applicable for all five crops. However, as shown in Tables 21 and 22, the Labofix model had the highest overall efficiencies for all the five crops tested. It had a near perfect removal efficiency for soybeans; the lowest efficiency was 43% for corn. The highest efficiency of the N.S.L. model was for soybeans, which was about 57% on the average; the lowest efficiency was 14% for corn. The highest efficiency of the CD-XT3 model was for barley, which was about 89% on the average; the lowest was only about 4% for soybeans. It should be noted that the CD-XT 3 model is designed for use in removal of dockage rather than broken and shrunken kernels, and a low overall removal efficiency is expected.

TABLE 21. Means ± Standard Deviation and Range for Overall Removal Efficiency Corresponding to Each Unit.

Crop	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRW Wheat	77.29 ± 6.97 68.1 ~ 96.6	85.31 ± 6.05 77.3 ~ 106.0	20.01 ± 2.03 16.3 ~ 22.7	36.41 ± 6.45 28.9 ~ 48.3	11.49 ± 1.37 9.43 ~ 13.73	12.17 ± 0.99 9.9 ~ 13.3
Durum Wheat	68.70 ± 8.58 57.6 ~ 77.5	76.18 ± 8.79 60.4 ~ 85.6	21.04 ± 0.64 19.9 ~ 22.0	21.24 ± 1.28 18.9 ~ 23.2	17.57 ± 0.25 17.1 ~ 18.0	17.64 ± 0.27 17.2 ~ 18.0
Barley	87.46 ± 2.44 83.8 ~ 91.0	88.94 ± 3.68 83.1 ~ 93.9	30.37 ± 1.49 27.3 ~ 32.5	32.47 ± 1.47 29.5 ~ 35.0	36.23 ± 2.47 33.2 ~ 39.4	36.92 ± 0.65 35.7 ~ 38.0
Corn	41.58 ± 3.61 35.4 ~ 47.7	44.22 ± 3.15 36.6 ~ 48.5	14.41 ± 1.20 13.0 ~ 18.5	14.20 ± 0.73 12.8 ~ 15.7	23.58 ± 1.24 21.6 ~ 26.4	22.37 ± 1.11 19.8 ~ 24.0
Soybeans	100.55 ± 1.57 95.4 ~ 102.6	100.46 ± 1.34 96.1 ~ 102.0	59.90 ± 2.81 53.4 ~ 64.6	54.82 ± 1.90 52.1 ~ 58.0	3.76 ± 0.15 3.5 ~ 4.0	3.97 ± 0.22 3.6 ~ 4.5

TABLE 22. Means ± Standard Deviations and Ranges of Overall Removal Efficiency at Different Moisture Content for Each Model.

Crop	Labofix		N.S.L.		CD-XT 3	
	MC 1 (11%)	MC 2 (15%)	MC 1 (11%)	MC 2 (15%)	MC 1 (11%)	MC 2 (15%)
HRW Wheat	80.62 ± 6.95 68.1 ~ 96.6	82.58 ± 8.61 69.8 ~ 106.1	28.97 ± 10.59 17.0 ~ 48.3	27.45 ± 8.65 16.3 ~ 45.5	10.99 ± 1.06 9.4 ~ 12.3	12.67 ± 0.69 11.1 ~ 13.7
Durum Wheat	80.23 ± 4.19 74.7 ~ 85.6	64.65 ± 5.86 50.0 ~ 74.6	20.61 ± 0.84 18.9 ~ 21.8	21.67 ± 0.87 20.2 ~ 23.4	17.42 ± 0.17 17.1 ~ 17.7	17.79 ± 0.18 17.2 ~ 18.0
Barley	86.90 ± 2.52 83.1 ~ 91.7	89.49 ± 3.28 83.8 ~ 93.9	30.32 ± 1.46 27.3 ~ 32.6	32.52 ± 1.42 29.8 ~ 35.0	35.34 ± 1.64 33.2 ~ 38.0	37.80 ± 0.94 36.2 ~ 39.4
Corn	40.59 ± 3.43 35.4 ~ 47.1	45.21 ± 1.89 40.6 ~ 48.5	14.25 ± 0.70 13.0 ~ 15.4	14.36 ± 1.23 12.8 ~ 18.5	23.43 ± 1.63 19.8 ~ 26.4	22.52 ± 0.67 21.4 ~ 23.8
Soybeans	101.37 ± 0.69 100.5 ~ 102.8	99.64 ± 1.48 95.4 ~ 100.8	59.15 ± 3.27 53.8 ~ 64.6	55.57 ± 2.78 52.1 ~ 60.3	3.82 ± 0.16 3.6 ~ 4.2	3.90 ± 0.26 3.5 ~ 4.5

III. Ease of Operation

The evaluation of ease of operation of each model was based on three parts:

1. Testing Time

Table 23 contains the results of average testing time for a test sample measured with a stop watch for each individual machine.

TABLE 23. Average Testing Times (minutes) of the Three Models for the Five Crops Tested.

Model / Crop	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRW Wheat	2.84	3.04	2.52	3.09	1.95	1.61
Durum Wheat	1.71	2.00	1.23	1.20	1.39	1.33
Barley	2.20	2.38	1.16	1.13	1.29	1.17
Soybeans	2.24	2.34	0.52	0.89	0.72	0.66
Corn	1.92	2.02	0.85	1.17	0.89	0.81
Average	2.18	2.36	1.26	1.50	1.25	1.12
	2.27		1.38		1.19	

The average values of testing time for the three models were found to be in the following order:

Labofix > N.S.L. > CD-XT 3

The average values were calculated based on all the tests for five crops: 1.19 minutes for

CD-XT3; 1.38 minutes for N.S.L.; and 2.27 minutes for Labofix.

2. Operation Noise

Table 24 contains the results of operation noise for each model.

TABLE 24. Average Noise Level Measurement (decibels) of the Three Models for the Five Crops Tested.

Model / Crop	Labofix	N.S.L.	CD-XT 3
HRW Wheat	78.33	89.33	86.17
Durum Wheat	78.67	87.67	84.33
Barley	77.50	89.00	87.33
Soybeans	87.10	90.33	98.30
Corn	89.50	89.50	98.00
Average	82.22	89.17	90.83

The operation noise was measured with a noise meter at a distance of one foot away from the machine where the operator usually was. The average values for the three models and five crops were found to be in the following order:

CD-XT3 > N.S.L. > Labofix

The average values were computed based on 5 crops: 82.22 decibels for Labofix; 89.17 for N.S.L.; and 90.83 for CD-XT3.

3. Ease of Changing Parts, Sieve-Self Cleaning, Feed Control and Air Control

The analysis of this part was based on ranking numbers which were given when the machine was operating. The results are shown in Table 25. In the table:

F - Feed control with weighted factor: excellent=3,good=2,fair=1;

A - Air control with weighted factor: excellent=3,good=2,fair=1;

S - Sieve cleaning with weighted factor: excellent=3,good=2,fair=1;

C - Changing parts with weighted factor: excellent=3,good=2,fair=1;

Av- Average values of F, A, S, and C.

TABLE 25. Ranking Numbers for Feed and Air Control,Sieve Cleaning,and Changing Parts.

Crop	Model	F	A	S	C	AV
HRW Wheat	Labofix	2	3	2	1	2.00
	N.S.L.	1	3	2	2	2.00
	CD-XT 3	3	1	2	3	2.25
Durum Wheat	Labofix	2	3	2	1	2.00
	N.S.L.	1	3	2	2	2.00
	CD-XT 3	3	1	2	3	2.25
Barley	Labofix	2	3	2	1	2.00
	N.S.L.	1	3	3	2	2.25
	CD-XT 3	3	2	1	3	2.25
Soybeans	Labofix	2	3	2	1	2.00
	N.S.L.	2	3	3	2	2.50
	CD-XT 3	2	2	2	3	2.25
Corn	Labofix	3	3	2	1	2.25
	N.S.L.	3	3	3	2	2.50
	CD-XT 3	3	1	2	3	2.25

The Friedman's analysis, shown in Table 26, was applied to analyze the average ranking values. The following results of the Friedman's analysis was obtained:

$$\chi_r^2 = -2 < \chi^2_{0.05,2} = 5.991$$

Therefore, we can not reject the assumption that the average values of the three models were same.

TABLE 26. Friedman's Analysis for Ease of Operation.

Crops	Models		
	1 (Labofix)	2 (N.S.L.)	3 (CD-XT 3)
HRW wheat	2.00 (1)	2.00 (1)	2.25 (3)
Durum	2.00 (1)	2.00 (1)	2.15 (3)
Barley	2.00 (1)	2.25 (3)	2.25 (3)
Corn	2.25 (1)	2.50 (3)	2.25 (1)
Soybeans	2.00 (1)	2.50 (3)	2.25 (2)
Rank sum (R_i)	5	11	12

$$\chi_r^2 = \frac{12}{ba(a+1)} \Sigma R_i^2 - 3b(a+1)$$

$$= \frac{12}{(5)(3)(3+1)}\left[(5)^2 + (11)^2 + (12)^2\right] - (3)x\ (5)(3+1)$$

$$= (0.2)(290) - 60 = 58 - 60 = -2$$

$$v = a - 1 = 2$$

$$\textit{From } \chi^2 \textit{ Table, } \chi^2_{0.05,2} = 5.991$$

Thus, we cannot reject Ho, the hypothesis that the average values for ranking the three models are the same.

IV. Comparison Between Test Results and Data from KSGIS

In addition to analyses of various factors for performance of the three models, the laboratory test results were compared with results of official grading. For official grading, one duplicate set of test samples of each impurity level and moisture content for the 5 crops was prepared, and the 30 samples were sent to the Kansas State Grain Inspection Service (KSGIS), Topeka, Kansas. Data for the samples inspected by KSGIS are presented in Table A.55 through Table A.59 in the Appendix.

The percentages of total impurities and broken materials found in the samples checked by the KSGIS, and the test results of the project are presented graphically in Figure 11 through Figure 15. As seen in these figures, a good linear relationship between our results and those by the KSGIS was obtained. In the graphs, if the slope of a line was greater than 1, the total impurities or broken materials separated by the machine were more than those removed by the KSGIS.

The amount of impurities separated by the CD-XT3 was much less than those by the KSGIS for all other crops except corn. The amount of impurities separated by the N.S.L. model was less than those done by the KSGIS for all crops. Compared to the data from the KSGIS, the Labofix model could separate about an equal amount, or more impurities, from a given sample for all crops except barley.

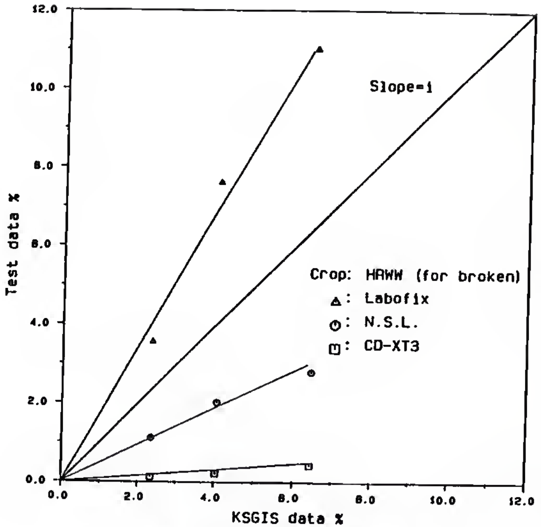


Fig.11a. Comparison between KSGIS and Test Data on Broken Materials Removed.

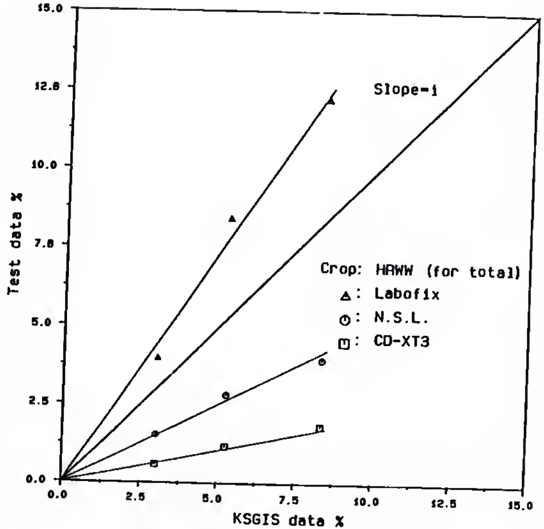


Fig.11b. Comparison between KSGIS and Test Data on Total Impurities Removed.

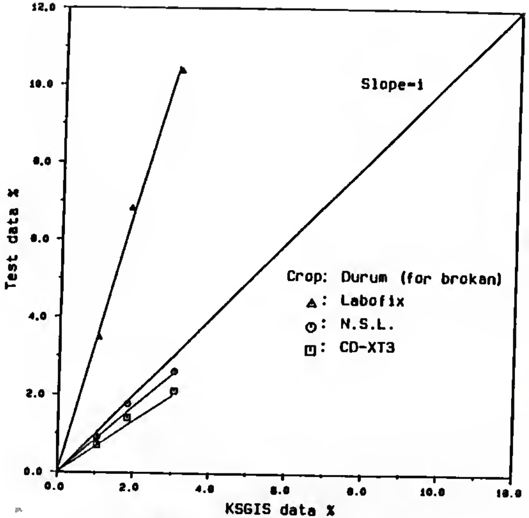


Fig.12a. Comparison batween KSGIS and Test Data
on Broken Materials Removed.

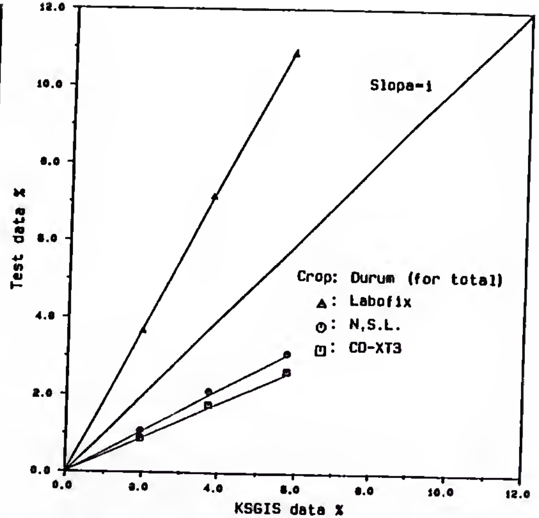


Fig.12b. Comparison between KSGIS and Tast Data
on Total Impurities Ramoved.

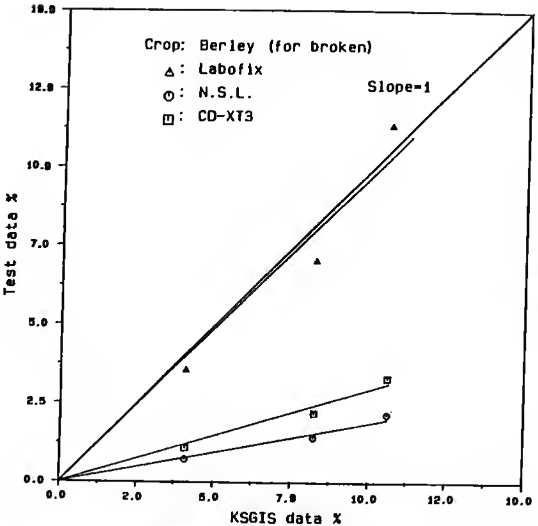


Fig.13e. Comperison between KSGIS end Test Deta on Broken Meteriels Removed.

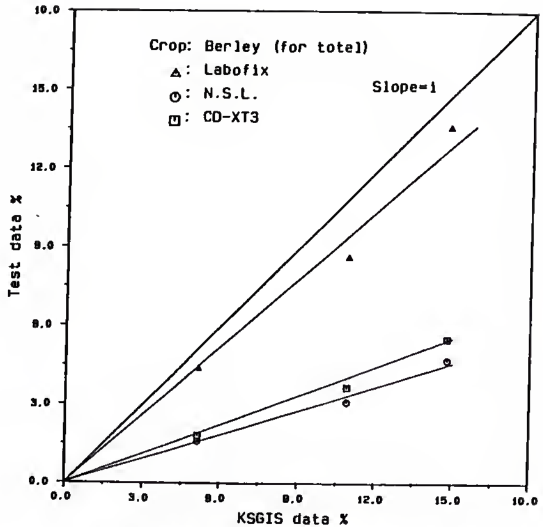


Fig.13b. Comperison between KSGIS and Test Dete on Total Impurities Removed.

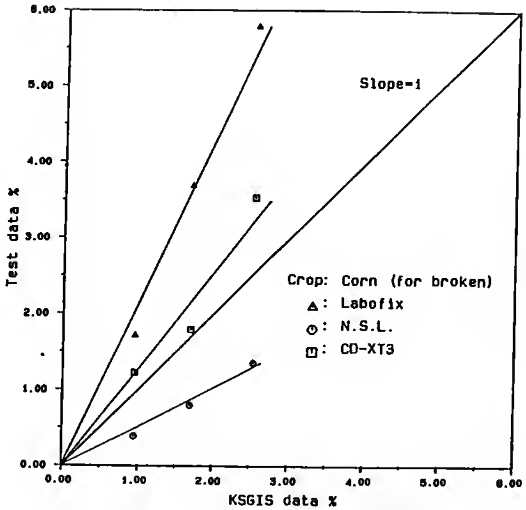


Fig.14a. Comparison between KSGIS and Test Data on Broken Materials Removad.

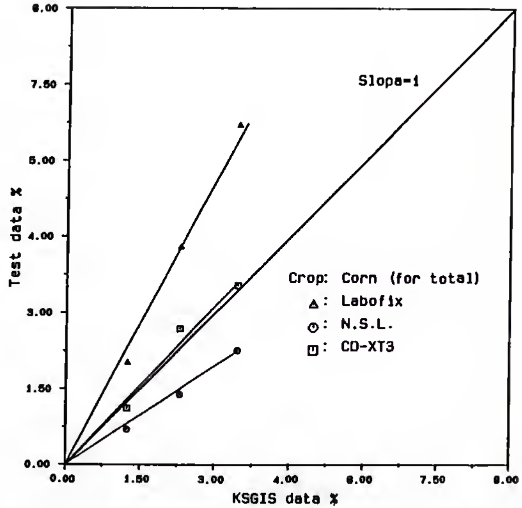


Fig.14b. Comparison betwaen KSGIS and Test Data on Total Impuritias Removad.

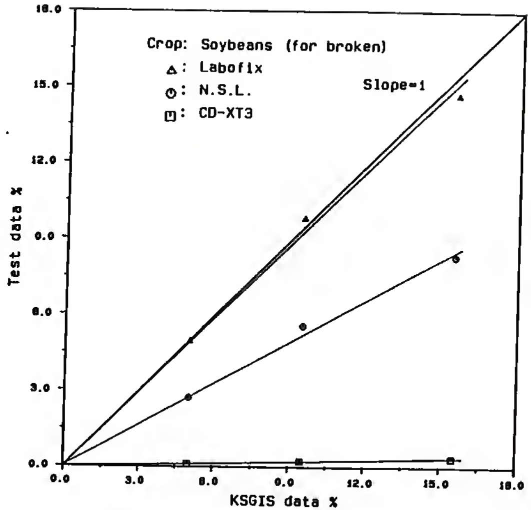


Fig.15a. Comparison between KSGIS and Test Data on Broken Materials removed.

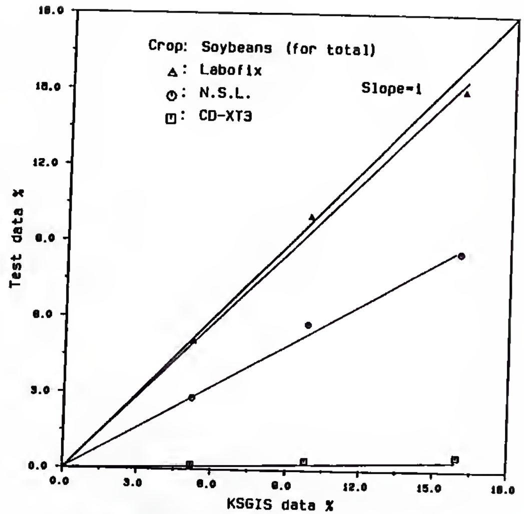


Fig.15b. Comparison between KSGIS and Test Data on Total Impurities Removed.

V. Summary of the Overall Evaluation for Grain Separation Performances by the Three Models Tested

The average values of overall removal efficiencies for total impurities are shown in Table 27:

TABLE 27. Average values of overall removal efficiency for total impurities.

CROP	Labofix	N.S.L.	CD-XT3
HRW Wheat	81.6%	28.2%	11.8%
Durum	72.4%	21.1%	17.6%
Barley	88.2%	31.4%	36.6%
Corn	42.9%	14.3%	23.0%
Soybeans	100.0%	57.4%	3.9%

Table 28 shows an evaluation summary for grain separation performances by the three cleaning models tested by ranking them in numbers:

TABLE 28. Summary on Evaluation of the Three Models (Ranking).

Evaluation of	Labofix	N.S.L.	CD-XT3
Accuracy	1*	2	3
Precision	2	3	1
Reproducibility			
a. Replicate	2	1	2
b. Unit	3	2	1
Applicability	1	2	3
Ease of operation			
a. Testing time	3	2	1
b. Noise level	1	2	3
c. Others**	3	1	1
Test vs KSGIS	1	2	3

*1 = best, 2 = good, 3 = fair.
**air control,feed control,sieve cleaning,changing parts.

Some strengths and weaknesses of each model observed during grain sample testing are summarized in Table 29:

TABLE 29. Strengths and weaknesses of the three models investigated in the research project.

Strengths and weaknesses of the three models tested			
	Labofix	N.S.L.	CD-XT3
Strength	removes broken kernels with indented cylinder; removes light materials with a cyclone collector; high removal efficiency.	removes light materials with double suction aspiration system; compact structure.	removes foreign materials with a riddle; good reproducibility.
Weakness	problems in feeding system and adjustment of trough; longer testing time; lower reproducibility.	problems in feeding system; the cloth guard retained grain kernels on sieve; needs proper size of sieves for brokens; lower reproducibility.	problem in sieve-self cleaning; aspirator blew dust to the air; needs additional sieves for brokens.

No model tested was applicable for all five crops with respect to the overall removal efficiency and reproducibility. However, it is believed that the removal efficiency and other features of each model can be improved with some modifications. Eventually, a modified version of one of the models tested may be used for the U.S. grain grading system so that a hand separation step for broken and shrunken kernels would be eliminated. An improved model can be designed by combining the strengths of each of the three models tested for separating the sound kernel portion or all impurity portions from a given grain sample.

CONCLUSIONS

The following conclusions can be drawn from the research project:

A. The Labofix model gives the highest removal efficiency among the three models tested for removing total impurities and broken materials. It has a good feature for separating broken kernels by using a rotating indented cylinder. For separating light materials, it has a good aspiration system with a cyclone dust collector. However, it also has some weaknesses, such as the feeding system and the trough adjustment used for transfering broken kernels.

B. The N.S.L. model has a very good feature on the aspiration system for separating light materials, which has two pick up points located at the beginning and end of the grain flow. The feeding system was designed with a timing control and 'off-on' switch in the hopper, but the feed control valve was not continuously turned so that it was hard to adjust the feed flow for different sizes of grains. The removal efficiency could be improved if proper sieves are available.

C. The CD-XT3 model has a very good feature to remove foreign materials by using riddles. The removal efficiency for broken materials could be improved if proper sieves are installed. The removal efficiency for light materials could be improved by using a higher setting on the air control valve. The aspirator needs a filtration system to collect dust.

D. Moisture content had more effect than impurity level on the removal efficiencies. For overall efficiency, the analysis showed that 63% of the tests was significantly affected by moisture content, but only 2% by impurity level.

E. The difference between the two units of Labofix and N.S.L. models was statistically significant for 60%-80% of the tests. In contrast, a significant difference between the two units of the CD-XT3 model was shown in only 40% for all the crops. The reproducibility of the CD-XT3 model was better than the other two models.

F. A linear relationship between the laboratory test results and those by the KSGIS was obtained. Compared to the results from the KSGIS, the Labofix model could separate an amount equal to or more impurities from a grain sample for all crops except barley.

G. No model tested is applicable for a complete removal of the total impurities in all the five crops examined. However, each model can be improved to give higher removal efficiencies after proper modifications are made. A better model can be designed by combining the strengths of each of the three models for separating the sound kernel portion, or all impurity portions, from a given grain sample.

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APPENDIX

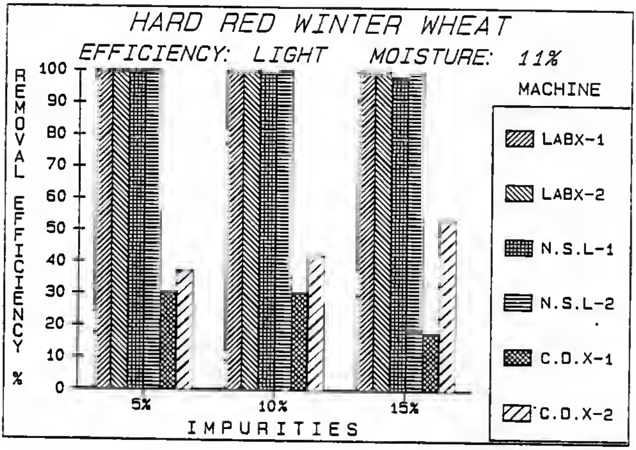

Figure A.1. Removal Efficiency of Light materials by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Hard Red Winter Wheat at 11% Moisture.

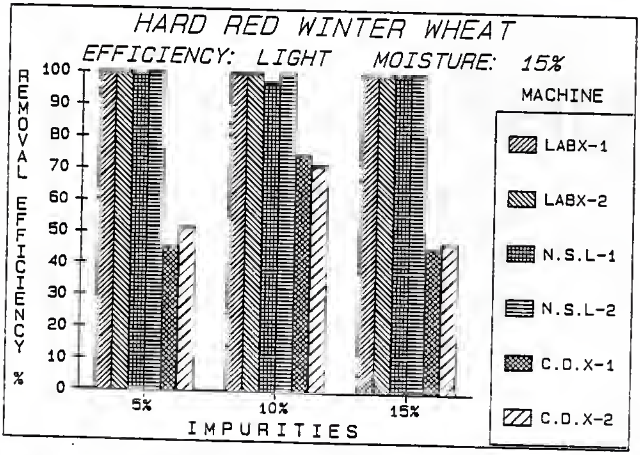

Figure A.2. Removal Efficiency of Light materials by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Hard Red Winter Wheat at 15% Moisture.

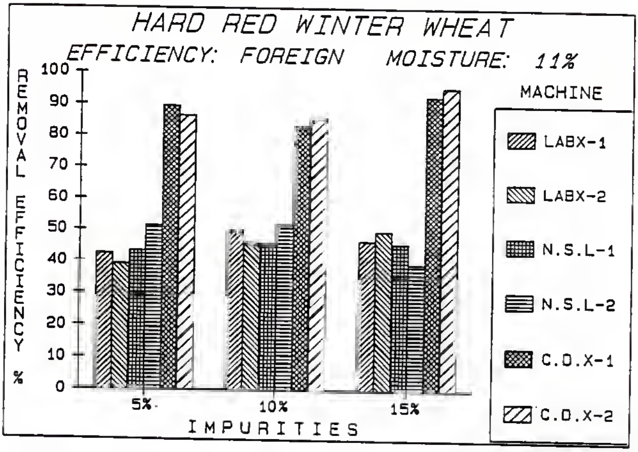

Figure A.3. Removal Efficiency of Foreign Materials by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Hard Red Winter Wheat at 11% Moisture.

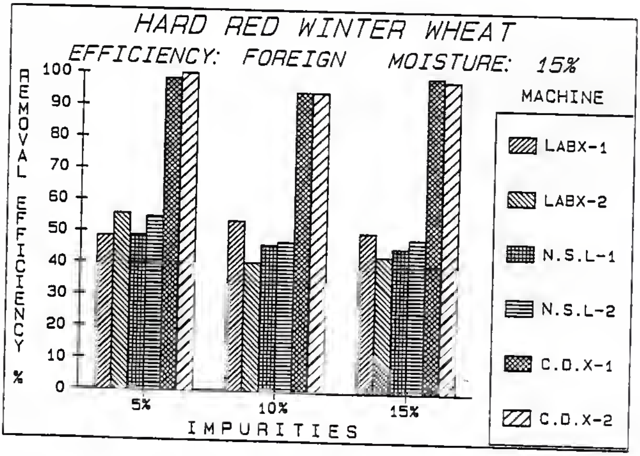

Figure A.4. Removal Efficiency of Foreign Materials by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Hard Red Winter Wheat at 15% Moisture.

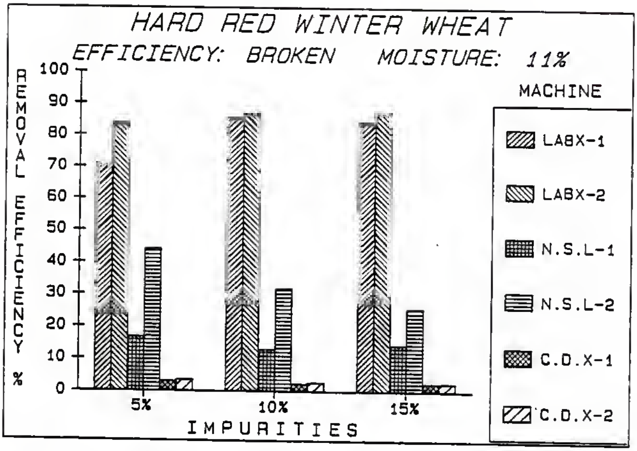

Figure A.5. Removal Efficiency of Broken and Fines by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Hard Red Winter Wheat at 11% Moisture.

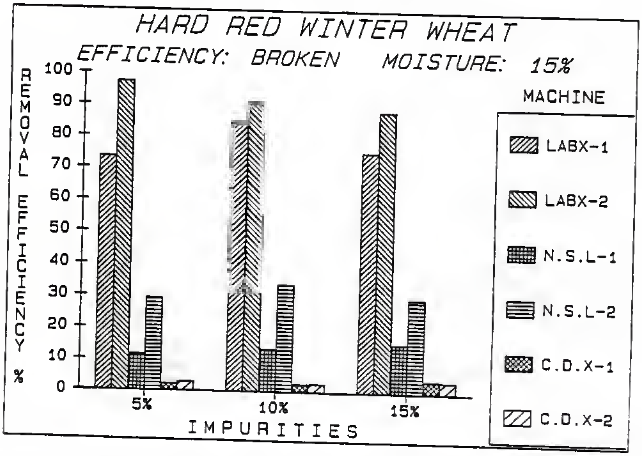

Figure A.6. Removal Efficiency of Broken and Fines by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Hard Red Winter Wheat at 15% Moisture.

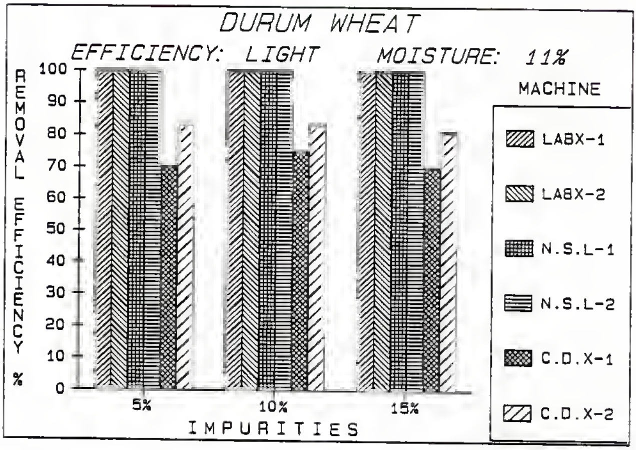

Figure A.7. Removal Efficiency of Light materials by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Durum Wheat at 11% Moisture.

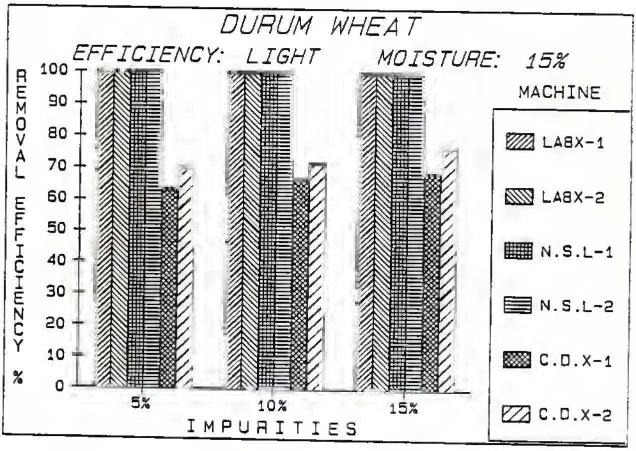

Figure A.8. Removal Efficiency of Light materials by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Durum Wheat at 15% Moisture.

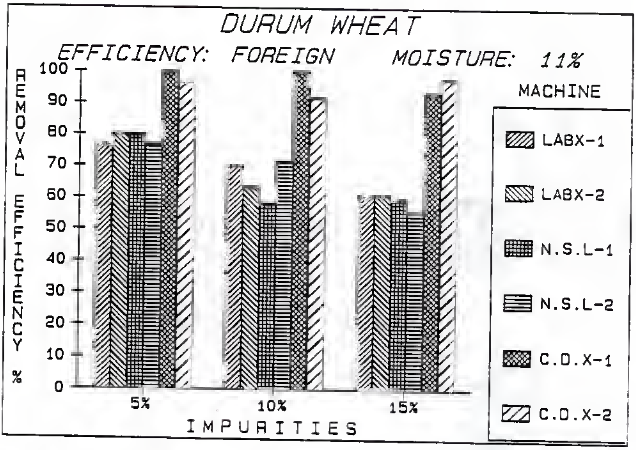

Figure A.9. Removal Efficiency of Foreign Materials by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Durum Wheat at 11% Moisture.

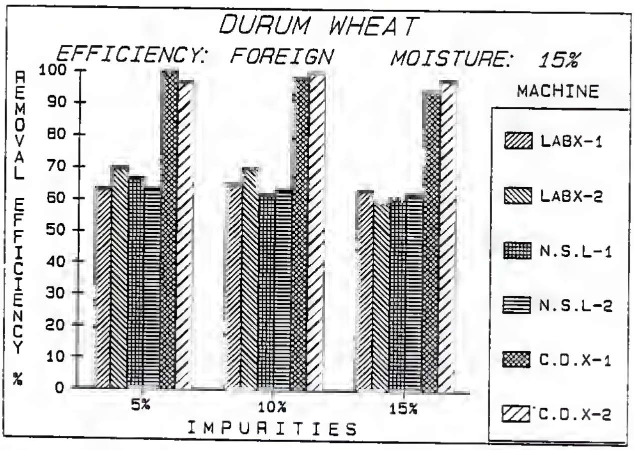

Figure A.10. Removal Efficiency of Foreign Materials by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Durum Wheat at 15% Moisture.

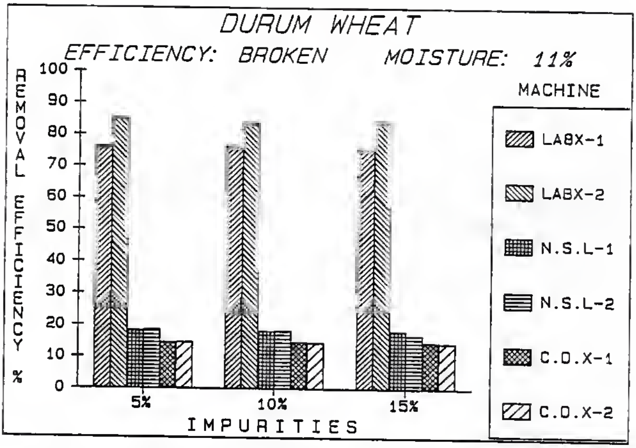

Figure A.11. Removal Efficiency of Broken and Fines by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Durum Wheat at 11% Moisture.

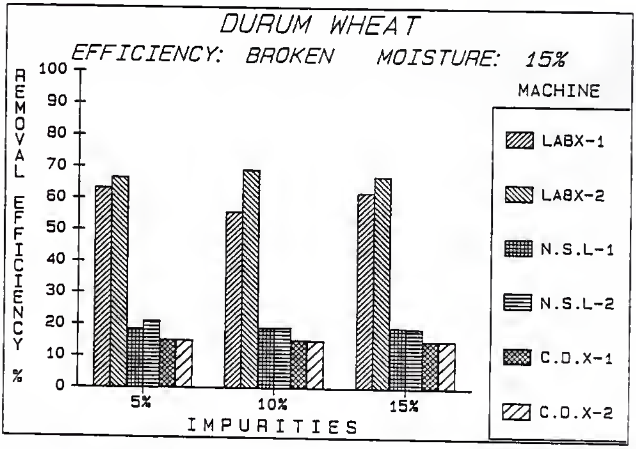

Figure A.12. Removal Efficiency of Broken and Fines by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Durum Wheat at 15% Moisture.

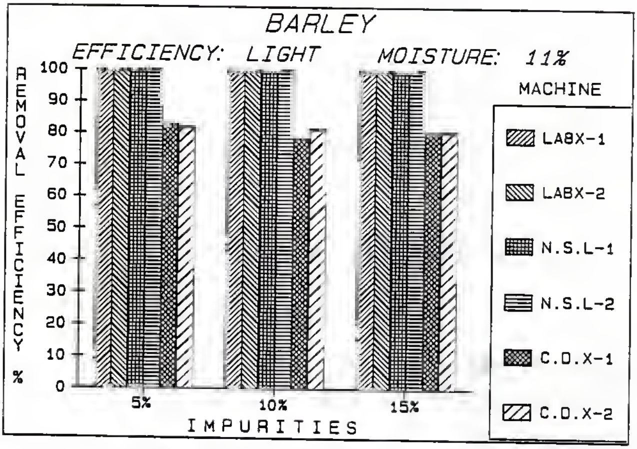

Figure A.13. Removal Efficiency of Light materials by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Barley at 11% Moisture.

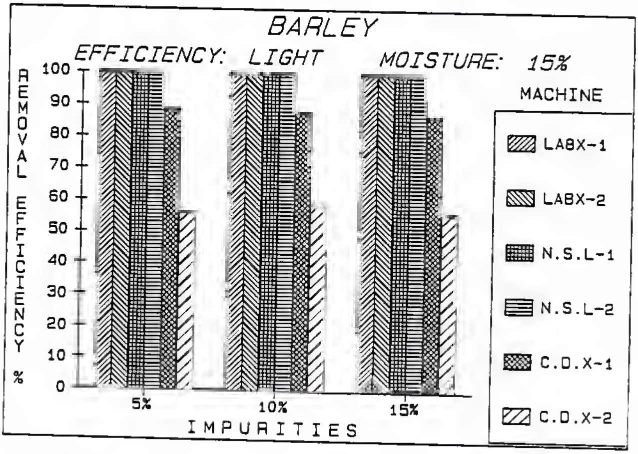

Figure A.14. Removal Efficiency of Light materials by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Barley at 15% Moisture.

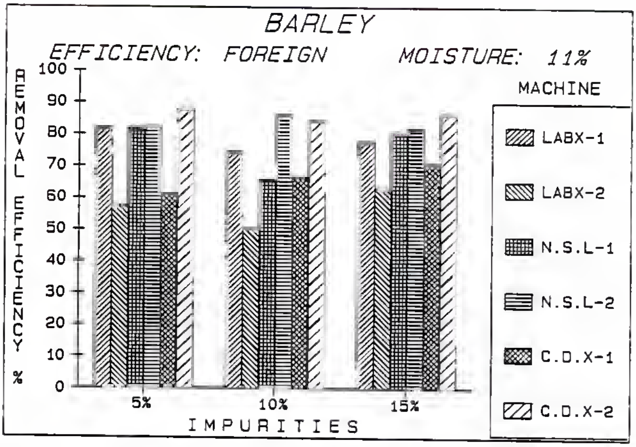

Figure A.15. Removal Efficiency of Foreign Materials by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Barley at 11% Moisture.

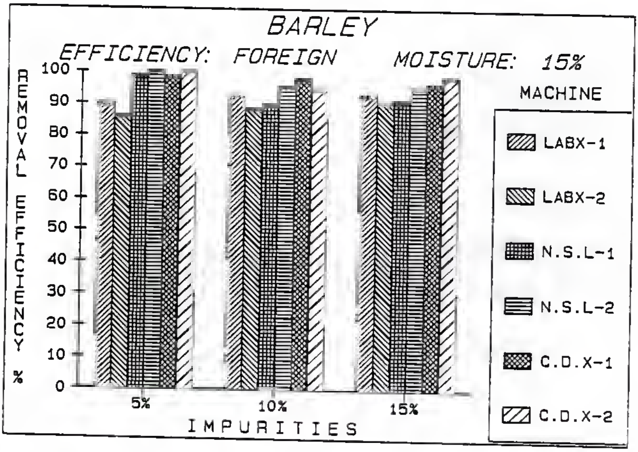

Figure A.16. Removal Efficiency of Foreign Materials by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Barley at 15% Moisture.

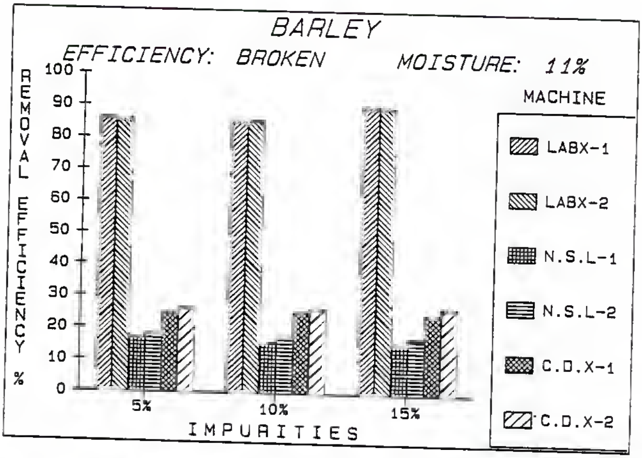

Figure A.17. Removal Efficiency of Broken and Fines by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Barley at 11% Moisture.

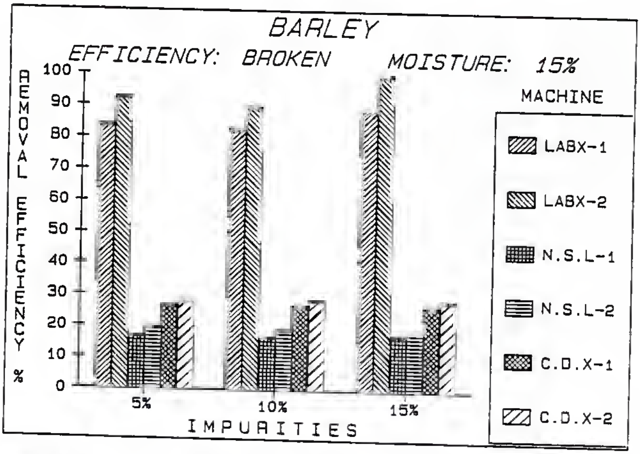

Figure A.18. Removal Efficiency of Broken and Fines by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Barley at 15% Moisture.

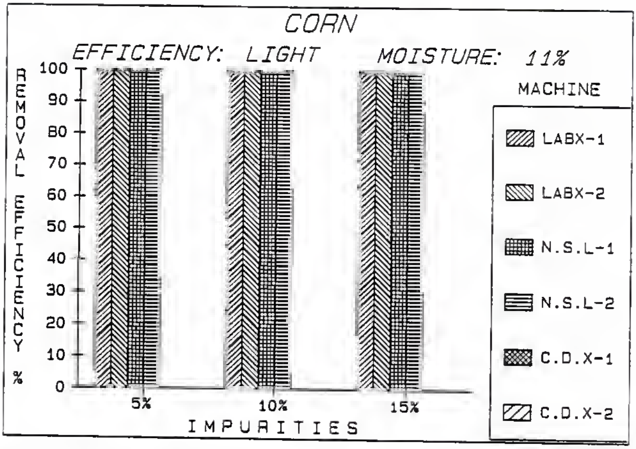

Figure A.19. Removal Efficiency of Light materials by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Yellow Dent Corn at 11% Moisture.

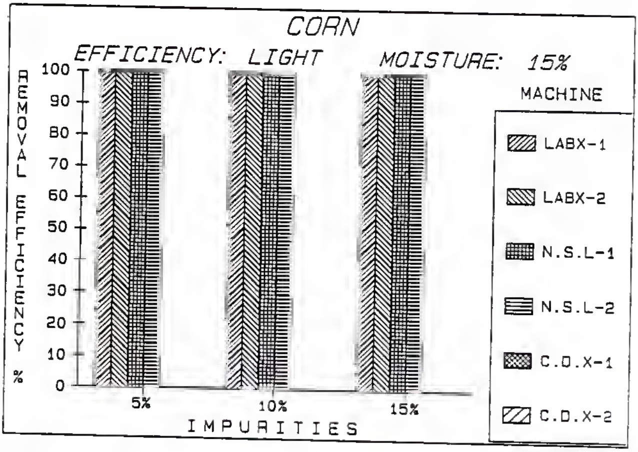

Figure A.20. Removal Efficiency of Light materials by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Yellow Dent Corn at 15% Moisture.

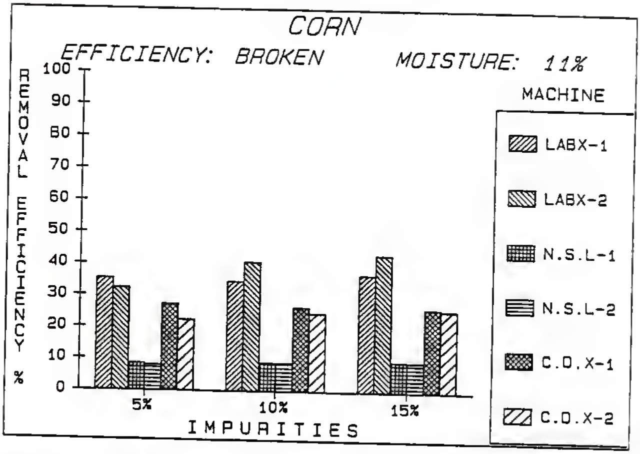

Figure A.21. Removal Efficiency of Broken and Fines by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Yellow Dent Corn at 11% Moisture.

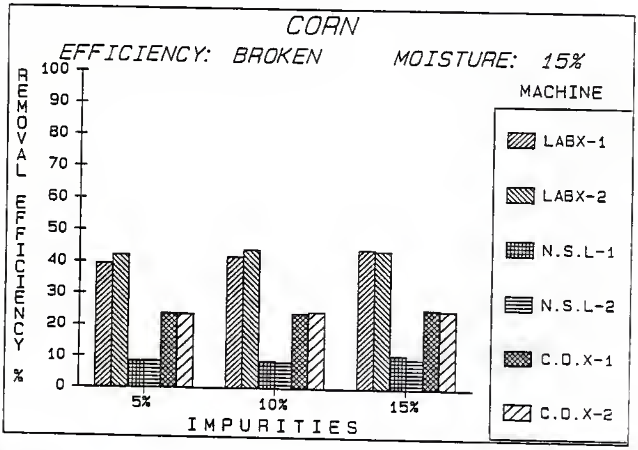

Figure A.22. Removal Efficiency of Broken and Fines by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Yellow Dent Corn at 15% Moisture.

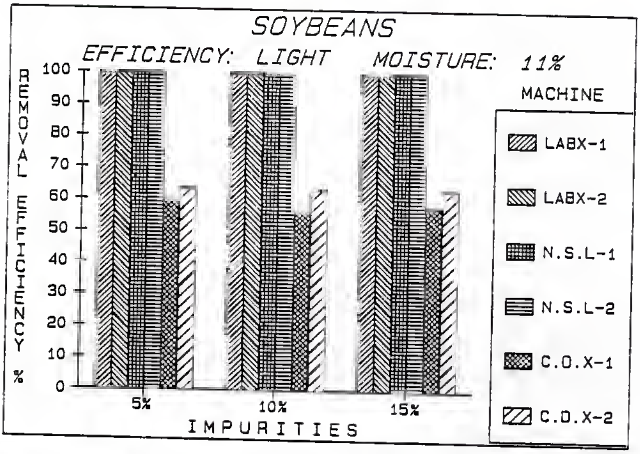

Figure A.23. Removal Efficiency of Light materials by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Soybeans at 11% Moisture.

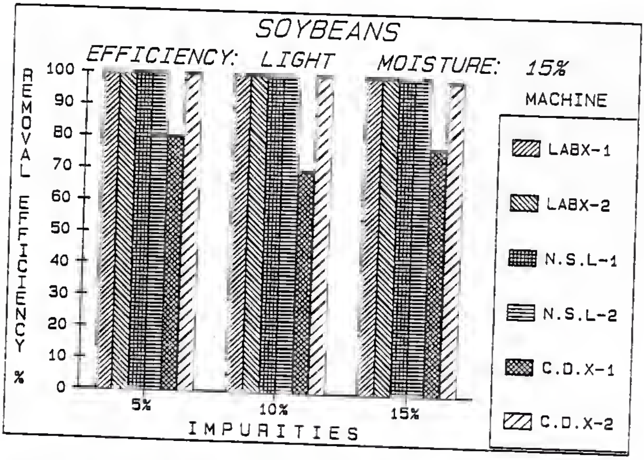

Figure A.24. Removal Efficiency of Light materials by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Soybeans at 15% Moisture.

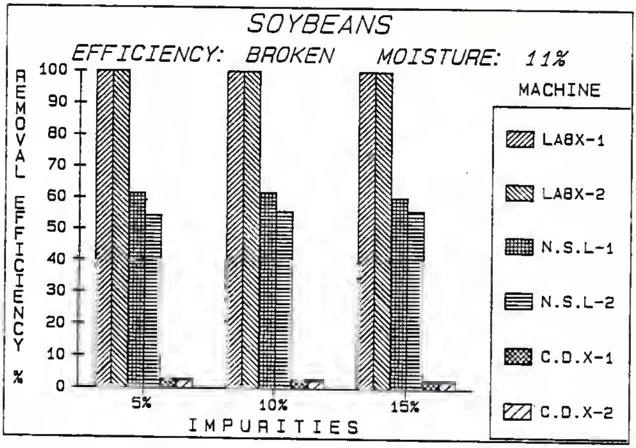

Figure A.25. Removal Efficiency of Broken and Fines by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Soybeans at 11% Moisture.

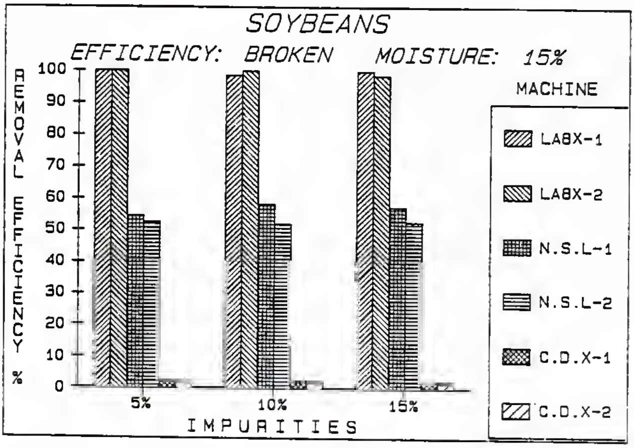

Figure A.26. Removal Efficiency of Broken and Fines by Two Units Each of Labofix,N.S.L.,and CD-XT3 Models for Soybeans at 15% Moisture.

TABLE A.Ia. Test Results on Light Materials and Broken Materials Removed from Hard Red Winter Wheat by Labofix (grams)

Fraction	Moisture content	Impurity levels					
		5%		10%		15%	
		unit1	unit2	unit1	unit2	unit1	unit2
Light	11%	3.3 3.4 3.0	4.1 6.4 5.4	4.9 6.7 7.5	9.2 8.5 7.9	11.9 9.6 8.9	12.5 13.4 12.4
	15%	3.6 3.7 3.2	14.6 6.7 6.1	10.3 11.3 10.7	10.8 11.3 12.4	8.6 12.6 10.3	15.7 16.4 15.7
Broken	11%	31.4 31.8 30.3	35.7 39.0 35.3	68.8 67.7 88.6	76.6 73.3 78.9	112.7 111.3 108.8	108.8 116.2 119.4
	15%	32.6 33.5 30.8	48.7 40.9 38.7	73.1 74.0 75.8	77.6 78.4 83.6	98.8 99.9 99.5	118.9 115.3 115.2

TABLE A.Ib. Test Results on Light Materials and Broken Materials Removed from Hard Red Winter Wheat by N.S.L.(grams)

Fraction	Moisture content	Impurity levels					
		5%		10%		15%	
		unit1	unit2	unit1	unit2	unit1	unit2
Light	11%	6.0 5.7 6.0	21.6 20.2 18.5	9.1 7.8 5.0	37.2 24.5 16.9	13.1 7.3 5.7	31.3 30.5 23.1
	15%	2.8 2.9 2.6	13.8 11.9 12.8	5.3 3.7 5.8	20.7 24.4 17.7	12.1 16.1 10.6	27.9 25.9 35.2
Broken	11%	7.5 7.3 7.2	20.8 19.5 17.9	13.1 11.5 9.3	36.0 24.6 23.1	22.3 17.9 16.1	35.1 33.0 33.3
	15%	5.1 5.4 4.7	13.7 12.1 12.9	10.2 14.8 10.9	23.8 28.0 37.8	19.8 23.1 18.5	37.7 38.2 42.0

TABLE A.Ic. Test Results on Light Materials and Broken Materials Removed from Hard Red Winter Wheat by CD-XT3 (grams)

Fraction	Moisture content	Impurity levels					
		5%		10%		15%	
		unit1	unit2	unit1	unit2	unit1	unit2
Light	11%	0.6	0.8	1.4	1.7	1.1	2.9
		0.6	0.8	1.4	1.7	1.1	3.4
		0.6	0.6	1.1	1.6	1.0	3.4
	15%	1.2	0.9	3.0	2.9	2.5	2.6
		0.9	1.2	2.3	2.7	3.1	3.1
		0.7	0.9	3.6	3.0	2.7	2.8
Broken	11%	1.1	1.7	1.8	2.4	3.3	3.6
		1.7	1.9	1.8	2.1	3.3	3.5
		1.2	1.1	2.0	2.9	3.6	3.3
	15%	0.8	1.2	2.4	2.3	4.6	5.4
		0.9	1.2	2.6	2.1	5.3	5.0
		1.1	1.4	1.8	2.5	5.9	4.8

TABLE A.IIa. Test Results on Light Materials and Broken Materials Removed from Durum Wheat by Labofix (grams)

Fraction	Moisture content	Impurity levels					
		5%		10%		15%	
		unit1	unit2	unit1	unit2	unit1	unit2
Light	11%	2.3	4.6	4.2	10.6	6.7	16.1
		3.0	5.0	4.4	10.1	8.0	15.4
		3.2	4.8	4.9	9.6	8.2	13.8
	15%	3.0	5.2	6.0	8.4	8.5	13.3
		3.1	4.3	6.2	8.9	8.6	13.8
		2.8	4.6	5.3	9.2	8.1	13.3
Broken	11%	36.2	41.0	73.5	80.2	107.4	121.6
		36.3	40.7	72.9	80.7	107.8	121.1
		36.8	40.6	73.0	79.9	111.1	121.2
	15%	31.7	31.6	55.9	70.8	90.1	95.9
		27.2	35.6	57.9	64.9	87.8	96.6
		32.1	28.5	46.7	63.1	89.8	97.2

TABLE A.IIb. Test Results on Light Materials and Broken Materials Removed from Durum Wheat by N.S.L. (grams)

Fraction	Moisture content	Impurity levels					
		5%		10%		15%	
		unit1	unit2	unit1	unit2	unit1	unit2
Light	11%	4.1 5.0 4.2	6.1 6.0 5.2	7.9 9.8 8.5	12.2 11.2 10.3	13.5 13.8 10.8	12.6 12.7 11.3
	15%	4.4 2.8 4.1	5.8 6.5 6.8	8.2 8.4 8.9	10.2 11.3 10.2	11.7 13.2 12.9	14.9 14.8 12.8
Broken	11%	8.5 9.1 8.6	9.0 9.0 8.6	17.4 17.8 16.9	17.9 17.4 17.1	27.0 26.3 25.2	24.5 24.4 23.7
	15%	8.8 8.4 9.3	10.0 9.9 10.3	18.0 18.2 18.3	18.4 18.9 17.6	27.0 28.1 27.6	27.5 26.0 28.0

TABLE A.IIc. Test Results on Light Materials and Broken Materials Removed from Durum Wheat by CD-XT3 (grams)

Fraction	Moisture content	Impurity levels					
		5%		10%		15%	
		unit1	unit2	unit1	unit2	unit1	unit2
Light	11%	0.7 0.7 0.7	0.8 0.9 0.8	1.4 1.5 1.6	1.6 1.7 1.7	1.9 2.2 2.2	2.4 2.4 2.5
	15%	0.7 0.6 0.6	0.7 0.6 0.8	1.4 1.3 1.3	1.4 1.4 1.5	2.2 2.0 2.0	2.3 2.3 2.3
Broken	11%	7.0 6.9 7.1	7.0 6.9 7.0	13.9 14.0 13.8	14.1 13.8 13.8	21.0 21.1 21.1	21.0 20.7 20.9
	15%	7.2 7.2 7.3	7.2 7.1 7.2	14.6 14.6 14.6	14.5 14.4 14.4	21.6 21.7 21.7	21.7 21.5 21.6

TABLE A.IIIa. Test Results on Light Materials and Broken Materials Removed from Barley by Labofix (grams)

Fraction	Moisture content	Impurity levels					
		5%		10%		15%	
		unit1	unit2	unit1	unit2	unit1	unit2
Light	11%	7.3 7.2 7.1	6.9 6.7 7.1	14.0 14.4 14.1	14.4 13.7 13.9	22.4 22.3 21.2	20.9 21.3 21.6
	15%	8.1 7.7 7.9	8.7 8.4 7.9	15.7 15.3 15.3	15.4 15.3 15.6	22.8 23.4 23.5	23.1 23.5 23.7
Broken	11%	34.9 34.7 36.2	34.8 35.6 35.1	68.7 71.9 70.0	69.6 69.6 71.3	110.7 111.6 111.1	107.4 109.5 114.7
	15%	35.1 33.7 34.0	37.4 38.3 37.9	69.3 67.2 67.0	73.3 73.4 73.4	107.8 111.0 109.8	112.7 112.3 144.7

TABLE A.IIIb. Test Results on Light Materials and Broken Materials Removed from Barley by N.S.L. (grams)

Fraction	Moisture content	Impurity levels					
		5%		10%		15%	
		unit1	unit2	unit1	unit2	unit1	unit2
Light	11%	6.8 7.1 8.1	8.5 8.9 8.7	14.5 14.7 13.7	18.2 19.8 19.4	23.5 24.5 20.8	29.1 27.6 28.4
	15%	6.4 6.1 6.6	9.2 8.4 8.6	13.1 14.5 13.2	14.8 16.6 17.6	21.7 20.5 21.2	23.9 25.2 25.6
Broken	11%	6.8 6.7 7.1	7.3 7.0 7.8	13.7 12.4 12.7	14.6 14.8 14.5	20.0 20.4 18.4	21.7 22.1 21.0
	15%	6.6 6.9 7.2	8.0 7.6 8.5	13.7 14.0 13.5	15.4 15.7 16.0	22.1 21.4 21.5	23.2 23.7 24.2

TABLE A.IIIc. Test Results on Light Materials and Broken Materials Removed from Barley by CD-XT3 (grams)

Fraction	Moisture content	Impurity levels					
		5%		10%		15%	
		unit1	unit2	unit1	unit2	unit1	unit2
Light	11%	4.3 4.0 4.1	4.1 4.1 4.1	8.0 8.0 7.5	8.2 8.1 8.1	12.0 12.1 12.2	12.0 12.2 12.1
	15%	4.4 4.5 4.4	2.5 2.9 3.0	8.8 8.7 8.8	5.9 5.8 6.0	12.7 13.2 13.1	8.4 8.4 8.6
Broken	11%	10.1 10.1 10.3	10.7 10.4 11.2	20.5 20.8 21.1	21.4 22.0 21.6	30.6 30.6 31.1	32.6 33.9 33.6
	15%	10.7 11.2 10.9	11.6 11.7 11.7	22.4 22.2 21.7	23.7 23.9 23.0	32.9 32.7 33.7	35.0 35.8 35.3

TABLE A.IVa. Test Results on Light Materials and Broken Materials Removed from Corn by Labofix (grams)

Fraction	Moisture content	Impurity levels					
		5%		10%		15%	
		unit1	unit2	unit1	unit2	unit1	unit2
Light	11%	4.1 4.2 4.2	4.2 4.5 4.3	8.8 8.9 8.3	8.2 9.1 8.7	12.2 12.3 12.2	13.1 13.7 13.0
	15%	4.7 4.7 4.7	4.0 4.4 4.1	9.6 9.3 9.9	9.4 9.3 8.8	14.6 14.5 14.6	13.9 13.5 13.4
Broken	11%	17.3 15.3 16.0	14.3 15.6 14.6	32.7 29.4 32.9	37.0 38.1 37.1	50.4 48.5 53.7	61.3 61.6 56.0
	15%	17.3 18.8 18.4	19.5 19.2 19.6	39.5 37.4 38.4	42.5 39.4 39.6	60.4 60.5 62.5	58.7 62.0 61.1

TABLE A.IVb. Test Results on Light Materials and Broken Materials Removed from Corn by N.S.L. (grams)

Fraction	Moisture content	Impurity levels					
		5%		10%		15%	
		unit1	unit2	unit1	unit2	unit1	unit2
Light	11%	4.1 4.2 4.6	4.4 4.6 3.6	9.4 9.1 9.7	9.1 9.3 9.7	15.7 16.5 14.3	15.9 15.0 16.3
	15%	4.1 4.2 4.6	4.1 4.4 4.5	8.7 8.8 8.9	8.8 9.0 9.6	18.0 13.7 14.7	15.5 15.2 14.2
Broken	11%	4.1 3.5 4.0	4.0 4.2 4.2	8.5 7.5 8.5	7.8 7.8 8.8	13.6 14.1 11.7	13.3 11.1 14.6
	15%	4.0 3.8 4.0	3.4 4.4 4.2	7.2 8.6 8.1	7.0 7.9 8.0	18.8 13.4 12.8	13.5 12.4 13.7

TABLE A.IVc. Test Results on Light Materials and Broken Materials Removed from Corn by CD-XT3 (grams)

Fraction	Moisture content	Impurity levels					
		5%		10%		15%	
		unit1	unit2	unit1	unit2	unit1	unit2
Light	11%	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0
	15%	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0
Broken	11%	12.3 12.2 13.2	9.9 10.3 10.6	23.8 24.6 24.7	22.1 22.5 23.4	36.0 35.7 36.0	35.6 35.1 36.0
	15%	11.0 11.1 10.8	10.7 11.0 10.9	22.6 22.0 22.8	22.5 22.8 22.3	35.7 34.7 35.2	35.1 34.5 34.2

TABLE A.Va. Test Results on Light Materials and Broken Materials Removed from Soybeans by Labofix (grams)

Fraction	Moisture content	Impurity levels					
		5%		10%		15%	
		unit1	unit2	unit1	unit2	unit1	unit2
Light	11%	1.1 1.2 1.1	1.4 1.2 1.0	2.2 2.7 2.3	2.4 2.5 2.6	3.4 3.8 3.6	4.2 4.1 4.3
	15%	1.0 1.1 1.1	1.1 1.1 1.2	2.3 2.5 2.2	2.4 2.3 2.3	3.4 3.3 3.6	3.9 3.8 4.0
Broken	11%	50.3 49.1 50.4	49.9 49.8 50.0	99.9 99.8 98.8	99.5 98.9 99.5	148.2 148.3 148.1	148.1 147.9 148.9
	15%	49.3 49.4 49.3	49.2 49.4 49.0	98.1 93.4 98.2	97.7 97.8 98.3	147.2 146.9 146.1	146.8 141.2 146.1

TABLE A.Vb. Test Results on Light Materials and Broken Materials Removed from Soybeans by N.S.L. (grams)

Fraction	Moisture content	Impurity levels					
		5%		10%		15%	
		unit1	unit2	unit1	unit2	unit1	unit2
Light	11%	4.8 4.3 3.7	2.2 2.6 2.4	8.4 6.6 7.5	5.2 4.8 5.0	11.0 11.1 9.5	7.4 8.2 9.4
	15%	2.7 1.9 1.7	2.5 2.0 2.2	3.7 3.1 3.4	5.1 4.5 5.0	4.6 5.0 5.5	7.5 7.5 7.9
Broken	11%	31.3 29.4 29.6	26.5 27.3 25.9	61.0 61.6 59.2	53.9 56.0 54.2	91.7 87.4 87.0	82.8 83.4 81.3
	15%	27.8 25.7 26.6	25.3 26.6 25.3	58.3 54.7 58.2	51.0 50.5 51.4	84.2 84.8 84.1	78.9 75.1 78.2

TABLE A.Vc. Test Results on Light Materials and Broken Materials Removed from Soybeans by CD-XT3 (grams)

Fraction	Moisture content	Impurity levels					
		5%		10%		15%	
		unit1	unit2	unit1	unit2	unit1	unit2
Light	11%	0.6 0.6 0.6	0.7 0.6 0.6	1.2 1.0 1.2	1.3 1.2 1.3	1.8 1.7 1.7	1.9 1.8 2.0
	15%	0.8 0.8 0.8	1.0 1.0 1.0	1.3 1.5 1.4	2.1 2.0 2.0	2.2 2.4 2.4	2.9 3.0 3.1
Broken	11%	1.3 1.4 1.4	1.4 1.2 1.3	2.5 2.7 2.6	2.8 2.5 2.6	3.7 3.9 3.9	4.0 3.7 3.7
	15%	1.0 1.1 1.1	1.1 0.9 1.0	2.3 2.3 2.3	2.1 2.0 2.2	3.5 3.1 3.6	3.0 3.3 3.0

TABLE A.1a. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Hard Red Winter Wheat Machine: CD-XT 3 - 1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	10.28 12.30 10.56	10.12 9.43 10.18	10.03 11.17 9.87
	11.05 ±1.09	9.91 ±0.42	10.36 ±0.71
15%	11.76 11.14 11.66	13.21 12.36 12.93	12.47 13.73 13.59
	11.52 ±0.33	12.83 ±0.43	13.26 ±0.69

TABLE A.1b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Hard Red Winter Wheat Machine: CD-XT 3 - 1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	30.00 30.50 30.00	34.25 28.50 27.75	18.33 17.50 17.33
		30.17 ±0.29	30.17 ±3.56	17.72 ±0.54
	15%	58.00 44.00 33.50	75.75 57.00 91.00	40.83 50.83 44.67
		45.17 ±12.29	74.58 ±17.03	45.44 ±5.05
η_F	11%	86.00 96.00 86.00	86.50 73.38 89.00	89.08 108.83 84.50
		89.33 ±5.77	82.96 ±8.39	92.47 ±10.10
	15%	98.75 95.75 100.50	97.13 93.13 93.13	97.50 102.00 98.25
		98.33 ±2.40	94.46 ±2.31	99.25 ±2.41
η_B	11%	2.50 3.86 2.82	2.08 2.75 2.22	2.47 2.46 2.74
		3.06 ±0.71	2.35 ±0.35	2.56 ±0.16
	15%	1.75 1.95 2.59	2.74 2.99 2.09	3.45 4.02 4.48
		2.10 ±0.44	2.61 ±0.46	3.98 ±0.52

TABLE A.2a. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Hard Red Winter Wheat Machine: CD-XT 3 - 2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	12.32 12.18 10.04	10.91 9.85 12.16	11.77 12.26 12.17
	11.51 ±1.28	10.97 ±1.16	12.07 ±0.26
15%	12.03 12.92 12.78	12.69 12.24 13.22	13.17 13.31 12.83
	12.59 ±0.45	12.72 ±0.49	13.10 ±0.25

TABLE A.2b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Hard Red Winter Wheat Machine: CD-XT 3 - 2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	39.00 41.00 31.50	42.25 43.00 40.75	48.00 56.00 56.17
		37.17 ±5.01	42.00 ±1.15	53.39 ±4.67
	15%	45.50 61.50 47.00	71.25 67.75 74.75	44.00 51.33 46.17
		51.33 ±8.84	71.25 ±3.50	47.17 ±3.77
η_F	11%	91.00 85.00 83.00	85.25 75.63 96.00	93.50 96.08 96.33
		86.33 ±4.16	85.63 ±10.19	95.31 ±1.57
	15%	98.00 101.25 101.75	93.75 92.88 96.25	98.00 99.17 97.50
		100.33 ±0.25	94.29 ±1.75	98.22 ±0.85
η_B	11%	3.95 4.25 2.43	2.73 2.36 3.24	2.69 2.65 2.52
		3.55 ±0.98	2.78 ±0.44	2.62 ±0.09
	15%	2.75 2.68 3.14	2.66 2.39 2.88	4.05 3.78 3.61
		2.86 ±0.25	2.64 ±0.24	3.82 ±0.22

TABLE A.3a. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Hard Red Winter Wheat   Machine: Labofix - 1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	70.86 70.10 68.08	77.44 74.90 96.60	83.61 80.88 80.58
	69.68 ±1.44	82.98 ±11.86	81.69 ±1.67
15%	73.20 74.42 69.82	80.83 81.54 85.47	74.96 73.98 76.73
	72.48 ±2.38	82.61 ±2.50	75.22 ±1.40

TABLE A.3b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Hard Red Winter Wheat   Machine: Labofix - 1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0	100.00 ±0	100.00 ±0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0	100.00 ±0	100.00 ±0
η_F	11%	51.50 32.50 43.25	58.38 40.50 50.25	56.08 33.50 50.25
		42.42 ±9.53	49.71 ±8.95	46.61 ±11.72
	15%	49.75 43.00 52.75	46.13 43.88 70.88	55.58 41.92 53.17
		48.50 ±4.99	53.63 ±14.98	50.22 ±7.29
η_B	11%	71.3 72.2 68.9	78.1 76.9 100.7	85.4 84.3 82.5
		70.80 ±1.71	85.23 ±13.41	84.07 ±1.46
	15%	74.1 76.1 70.0	83.1 84.1 86.1	74.8 75.7 75.4
		73.40 ±3.11	84.43 ±1.53	75.30 ±0.46

TABLE A.4a. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Hard Red Winter Wheat Machine: Labofix - 2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	79.74 84.48 77.30	84.02 80.65 87.17	85.19 87.51 81.89
	80.51 ±3.65	83.95 ±3.26	84.86 ±2.83
15%	106.08 90.14 85.74	84.35 86.20 90.74	86.33 84.51 84.35
	93.99 ±10.70	87.10 ±3.29	85.06 ±1.10

TABLE A.4b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Hard Red Winter Wheat Machine: Labofix - 2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0	100.00 ±0	100.00 ±0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0	100.00 ±0	100.00 ±0
η_F	11%	53.50 30.00 34.00	42.25 41.63 53.50	46.75 49.17 52.75
		39.17 ±12.57	45.97 ±6.68	49.56 ±3.02
	15%	58.25 54.25 54.50	35.00 47.88 39.00	38.25 45.58 44.83
		55.67 ±2.24	40.63 ±6.59	42.89 ±4.03
η_B	11%	81.20 88.70 80.20	87.1 83.3 89.6	88.0 90.4 83.7
		83.37 ±4.65	86.67 ±3.17	87.37 ±3.39
	15%	110.70 93.00 87.90	88.1 89.1 95.0	90.1 87.3 87.2
		97.20 ±11.97	90.73 ±3.73	88.20 ±1.65

TABLE A.5a. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Hard Red Winter Wheat Machine: N.S.L. - 1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	21.76 22.56 21.98	20.97 18.82 17.00	22.22 19.56 18.46
	22.10 ±0.41	18.93 ±1.99	20.08 ±1.93
15%	19.86 17.84 16.30	17.16 21.65 19.82	20.98 22.70 20.23
	18.00 ±1.79	19.54 ±2.26	21.30 ±1.27

TABLE A.5b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Hard Red Winter Wheat Machine: N.S.L. - 1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 94.17
		100.00 ±0	100.00 ±0	98.06 ±3.37
	15%	100.00 100.00 100.00	100.00 91.50 100.00	100.00 100.00 100.00
		100.00 ±0	97.17 ±4.91	100.00 ±0
η_F	11%	35.50 51.50 43.00	48.13 41.50 46.88	42.08 45.33 49.75
		43.33 ±8.01	45.50 ±3.52	45.72 ±3.85
	15%	72.00 38.00 36.50	36.88 39.87 61.88	47.00 41.25 48.42
		48.83 ±20.08	46.21 ±13.65	45.56 ±3.80
η_B	11%	17.0 16.4 16.5	14.9 13.1 10.6	16.9 13.6 12.2
		16.63 ±0.32	12.87 ±2.16	14.23 ±2.41
	15%	11.5 12.3 10.7	11.60 16.80 12.40	15.0 17.5 14.0
		11.50 ±0.80	13.60 ±2.80	15.50 ±1.80

TABLE A.6a. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Hard Red Winter Wheat Machine: N.S.L. - 2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	48.32 48.22 44.18	43.41 33.75 30.85	29.93 28.85 30.31
	46.91 ±2.36	36.00 ±6.58	29.70 ±0.75
15%	35.94 32.30 34.20	32.00 35.43 45.47	33.23 33.97 34.99
	34.15 ±1.82	37.63 ±7.00	34.06 ±0.88

TABLE A.6b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Hard Red Winter Wheat Machine: N.S.L. - 2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0	100.00 ±0	100.00 ±0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0	100.00 ±0	100.00 ±0
η_F	11%	33.25 65.75 54.75	43.25 64.00 47.38	31.33 35.75 51.08
		51.25 ±16.53	51.54 ±10.98	39.39 ±10.37
	15%	56.00 52.00 56.25	52.25 43.38 45.88	51.58 56.08 37.75
		54.75 ±2.38	47.17 ±4.58	48.47 ±9.55
η_B	11%	47.3 44.3 40.7	40.9 28.0 26.2	26.6 25.0 25.3
		44.10 ±3.30	31.70 ±8.02	25.63 ±0.85
	15%	31.2 27.4 29.2	27.1 31.8 43.0	28.5 29.0 31.8
		29.27 ±1.90	33.97 ±8.17	29.77 ±1.78

TABLE A.7a. Removal Percentage Efficiencies (η_{IMP}), Depending upon Impurity Level of 5%, 10% and 15%

Grain type: Durum Machine: CD-XT.3-1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	17.40 17.20 17.60	17.30 17.50 17.40	17.13 17.53 17.27
	17.40 ±0.20	17.34 ±0.05	17.31 ±0.20
15%	17.80 17.60 17.80	18.00 17.80 17.90	17.67 17.73 17.73
	17.73 ±0.16	17.90 ±0.10	17.71 ±0.04

TABLE A.7b. Removal Efficiencies of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Durum Machine: CD-XT.3-1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	70.00 70.00 70.00	70.00 75.00 80.00	63.33 73.33 73.33
		70.00 ±0.00	75.00 ±5.0	70.00 ±5.77
	15%	70.00 60.00 60.00	70.00 65.00 65.00	73.33 66.67 66.67
		63.33 ±5.77	66.67 ±2.89	68.89 ±3.85
η_F	11%	100.00 100.00 100.00	100.00 100.00 100.00	93.33 100.00 86.67
		100.00 ±0.00	100.00 ±0.00	93.33 ±6.67
	15%	100.00 100.00 100.00	100.00 95.00 100.00	90.00 96.67 96.67
		100.00 ±0.00	98.33 ±2.89	94.44 ±3.85
η_B	11%	14.58 14.38 14.79	14.48 14.58 14.38	14.58 14.65 14.65
		14.58 ±0.21	14.48 ±0.10	14.63 ±0.04
	15%	15.00 15.00 15.21	15.21 15.21 15.21	15.00 15.07 15.07
		15.07 ±0.12	15.21 ±0.00	15.05 ±0.04

TABLE A.8a. Removal Percentage Efficiencies (η_{IMP}), Depending upon Impurity Level of 5%, 10% and 15%

Grain type: Durum Machine: CD-XT.3-2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	17.60 17.40 17.60	17.60 17.20 17.30	17.60 17.31 17.60
	17.53 ±0.12	17.37 ±0.21	17.50 ±0.17
15%	17.80 17.20 18.00	17.90 17.80 17.90	17.93 17.87 17.93
	17.67 ±0.42	17.87 ±0.06	17.91 ±0.03

TABLE A.8b. Removal Efficiencies of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Durum Machine: CD-XT.3-2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	80.00 90.00 80.00	80.00 85.00 85.00	80.00 80.00 83.33
		83.33 ±5.77	83.33 ±2.89	81.11 ±1.92
	15%	70.00 60.00 80.00	70.00 70.00 75.00	76.66 76.66 76.66
		70.00 ±10.00	71.67 ±2.89	76.66 ±0.00
η_F	11%	100.00 90.00 100.00	100.00 85.00 90.00	100.00 93.33 100.00
		96.67 ±5.77	91.67 ±7.64	97.78 ±3.85
	15%	100.00 90.00 100.00	100.00 100.00 100.00	96.67 100.00 100.00
		96.67 ±5.77	100.00 ±0.00	98.89 ±1.92
η_B	11%	14.58 14.38 14.58	14.64 14.38 14.38	14.58 14.38 14.51
		14.51 ±0.12	14.46 ±0.15	14.49 ±0.11
	15%	15.00 14.79 15.00	15.10 15.00 15.00	15.07 14.93 15.00
		14.93 ±0.12	15.03 ±0.06	15.00 ±0.07

TABLE A.9a. Removal Percentage Efficiencies (η_{IMP}), Depending upon Impurity Level of 5%, 10% and 15%

Grain type: Durum — Machine: Labofix-1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	76.20 76.00 77.00	77.00 76.40 76.20	74.66 75.07 77.47
	76.40 ±0.53	76.53 ±0.42	75.73 ±1.51
15%	66.80 57.60 69.40	59.20 61.20 50.00	63.40 61.73 63.13
	64.60 ±6.20	56.80 ±5.97	62.76 ±0.90

TABLE A.9b. Removal Efficiencies of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Durum — Machine: Labofix-1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
η_F	11%	80.00 80.00 70.00	75.00 75.00 60.00	53.33 60.00 70.00
		76.67 ±5.77	70.00 ±8.66	61.11 ±8.39
	15%	70.00 60.00 60.00	65.00 65.00 65.00	66.67 60.00 63.33
		63.33 ±5.77	65.00 ±0.00	63.33 ±3.33
η_B	11%	75.6 75.4 76.7	76.6 75.9 76.0	74.6 74.9 77.2
		75.90 ±0.70	76.17 ±0.38	75.57 ±1.42
	15%	66.6 56.7 66.9	58.2 60.3 48.6	62.6 61.0 62.4
		63.20 ±5.65	55.70 ±6.24	62.00 ±0.87

TABLE A.10a. Removal Percentage Efficiencies (η_{IMP}), Depending upon Impurity Level of 5%, 10% and 15%

Grain type: Durum   Machine: Labofix-2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	85.60 85.20 84.60	83.60 83.90 82.90	84.13 84.00 84.13
	85.13 ±0.50	83.47 ±0.51	84.09 ±0.08
15%	66.60 74.60 60.40	74.10 68.40 66.50	67.13 67.73 67.87
	67.20 ±7.12	69.67 ±3.96	67.58 ±0.39

TABLE A.10b. Removal Efficiencies of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Durum   Machine: Labofix-2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
η_F	11%	80.00 90.00 70.00	70.00 60.00 60.00	53.33 63.33 66.67
		80.00 ±10.00	63.33 ±5.77	61.11 ±6.94
	15%	70.00 70.00 70.00	65.00 75.00 70.00	60.00 66.67 53.33
		70.00 ±0.00	70.00 ±5.00	60.00 ±6.67
η_B	11%	85.4 84.8 84.6	83.5 84.1 83.0	84.4 84.1 84.2
		84.93 ±0.42	83.53 ±0.55	84.23 ±0.15
	15%	65.8 74.2 59.4	73.8 67.6 65.7	66.6 67.1 67.5
		66.47 ±7.42	69.03 ±4.24	67.07 ±0.45

TABLE A.11a. Removal Percentage Efficiencies (η_{IMP}), Depending upon Impurity Level of 5%, 10% and 15%

Grain type: Durum Machine: N.S.L.-1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	20.60 21.80 20.80	20.60 21.00 20.00	21.27 20.08 19.87
	21.06 ±0.64	20.53 ±0.50	20.41 ±0.76
15%	20.80 20.20 22.00	21.40 21.20 21.40	21.20 21.93 21.66
	21.00 ±0.92	21.33 ±0.12	21.60 ±0.37

TABLE A.11b. Removal Efficiencies of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Durum Machine: N.S.L.-1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
η_F	11%	80.00 80.00 80.00	60.00 60.00 55.00	63.33 63.33 53.33
		80.00 ±0.00	58.33 ±2.89	60.00 ±5.78
	15%	60.00 70.00 70.00	60.00 65.00 60.00	60.00 60.00 63.33
		66.67 ±5.77	61.67 ±2.89	61.11 ±1.92
η_B	11%	17.7 19.0 17.9	18.1 18.5 17.6	18.8 18.3 17.5
		18.20 ±0.70	18.07 ±0.45	18.20 ±0.66
	15%	18.3 17.5 19.4	18.8 19.1 19.0	18.8 19.5 19.2
		18.40 ±0.95	18.97 ±0.15	19.17 ±0.35

TABLE A.12a. Removal Percentage Efficiencies (η_{IMP}), Depending upon Impurity Level of 5%, 10% and 15%

Grain type: Durum Machine: N.S.L.-2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	21.60 21.60 20.60	21.60 20.80 20.30	19.53 19.33 18.87
	21.27 ±0.58	20.90 ±0.66	19.24 ±0.34
15%	23.00 23.20 23.40	21.60 22.20 20.70	21.53 20.73 21.23
	23.20 ±0.20	21.50 ±0.75	21.16 ±0.40

TABLE A.12b. Removal Efficiencies of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Durum Machine: N.S.L.-2

Removal efficiencies	Moisture content	Impurity levels 5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
η_F	11%	80.00 80.00 70.00	85.00 70.00 60.00	60.00 53.33 53.33
		76.66 ±5.77	71.66 ±12.58	55.56 ±3.85
	15%	50.00 70.00 70.00	60.00 65.00 55.00	60.00 70.00 53.33
		63.33 ±11.55	60.00 ±5.00	61.11 ±8.39
η_B	11%	18.8 18.8 17.9	18.6 18.1 17.8	17.0 16.9 16.5
		18.50 ±0.52	18.17 ±0.40	16.80 ±0.26
	15%	20.8 20.6 21.5	19.2 19.7 18.3	19.1 18.1 19.4
		20.97 ±0.47	19.07 ±0.71	18.87 ±0.68

TABLE A.13a. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Barley   Machine: CD-XT 3 - 1

Moisture Content (W.B.) \ Impurity level	5%	10%	15%
11%	33.40 33.72 33.24	34.63 33.59 33.68	34.03 34.06 34.60
	33.45 ±0.24	33.97 ±0.58	34.23 ±0.32
15%	38.30 39.40 37.98	39.22 38.73 38.22	38.13 38.10 39.20
	38.56 ±0.74	38.72 ±0.50	38.48 ±0.63

TABLE A.13b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Barley   Machine: CD-XT 3 - 1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	86.00 82.00 80.00	80.10 80.10 75.00	79.67 80.47 81.13
		82.67 ±3.05	78.40 ±2.94	80.42 ±0.73
	15%	88.40 89.40 87.20	87.70 87.40 88.00	84.87 88.07 87.47
		88.33 ±1.10	87.70 ±0.30	86.80 ±1.70
η_F	11%	58.25 65.50 59.00	76.25 59.50 63.63	70.75 69.83 71.67
		60.92 ±3.99	66.46 ±8.73	70.75 ±0.92
	15%	100.75 100.00 94.25	100.63 97.13 96.25	96.25 93.50 99.67
		98.33 ±3.56	98.00 ±2.32	96.47 ±3.09
η_B	11%	24.56 24.73 25.02	25.02 25.39 25.72	24.88 24.91 25.31
		24.77 ±0.23	25.38 ±0.35	25.03 ±0.24
	15%	26.10 27.39 26.49	27.32 27.10 26.49	26.76 26.60 27.41
		26.66 ±0.66	26.97 ±0.43	26.93 ±0.43

TABLE A.14a. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Barley Machine: CD-XT 3 - 2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	36.30	35.70	36.73
	35.66	37.23	37.37
	38.02	36.66	37.56
	36.66 ±1.22	36.53 ±0.77	37.22 ±0.43
15%	36.24	37.12	36.63
	37.62	37.39	37.30
	37.06	36.57	37.27
	36.97 ±0.69	37.03 ±0.42	37.07 ±0.38

TABLE A.14b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Barley Machine: CD-XT 3 - 2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	81.00	81.40	80.20
		81.60	82.20	81.00
		82.80	80.50	80.87
		81.80 ±0.92	81.37 ±0.85	80.69 ±0.43
	15%	50.20	59.00	55.67
		58.20	58.40	55.67
		59.40	59.50	57.07
		55.93 ±5.00	58.97 ±0.55	56.13 ±0.81
η_F	11%	85.50	77.25	87.67
		84.75	88.25	83.00
		92.75	87.13	88.33
		87.67 ±4.42	84.21 ±6.05	86.33 ±2.91
	15%	100.75	93.75	96.58
		104.50	95.38	98.67
		97.25	95.00	100.75
		100.83 ±3.63	94.71 ±0.85	98.67 ±2.08
η_B	11%	26.05	26.07	26.46
		25.27	26.77	27.59
		27.22	26.39	27.33
		26.18 ±0.98	26.41 ±0.35	27.13 ±0.59
	15%	28.24	28.93	28.46
		28.59	29.17	29.07
		28.46	28.07	28.66
		28.43 ±0.17	28.72 ±0.58	28.73 ±0.31

TABLE A.15a. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Barley Machine: Labofix - 1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	86.76 86.02 88.44	84.98 87.96 85.50	89.75 90.69 90.46
	87.07 ±1.24	86.15 ±1.59	90.30 ±0.49
15%	87.10 85.02 85.04	86.54 84.71 83.81	89.40 91.01 90.93
	85.72 ±1.20	85.02 ±1.39	90.45 ±0.91

TABLE A.15b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Barley Machine: Labofix - 1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0	100.00 ±0	100.00 ±0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0	100.00 ±0	100.00 ±0
η_F	11%	86.00 82.75 76.50	78.00 75.63 69.25	74.25 78.50 80.25
		81.75 ±4.83	74.29 ±4.52	77.67 ±3.09
	15%	86.25 95.00 87.75	90.63 94.13 85.63	94.50 88.17 96.58
		89.67 ±4.68	90.13 ±4.27	93.08 ±4.38
η_B	11%	85.2 84.6 88.2	83.8 87.7 85.3	90.00 90.70 90.30
		86.00 ±1.93	85.60 ±1.97	90.33 ±0.35
	15%	85.6 82.2 83.0	84.5 81.9 81.7	87.6 90.2 89.3
		83.60 ±1.78	82.70 ±1.56	89.03 ±1.32

TABLE A.16a. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Barley   Machine: Labofix - 2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	84.64 85.58 84.50	83.82 83.13 85.60	86.79 87.77 91.68
	84.91 ±0.59	84.18 ±1.27	88.74 ±2.59
15%	91.76 93.88 92.06	90.58 90.11 90.46	92.31 92.13 93.85
	92.57 ±1.15	90.44 ±0.29	92.77 ±0.95

TABLE A.16b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Barley   Machine: Labofix - 2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0	100.00 ±0	100.00 ±0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0	100.00 ±0	100.00 ±0
η_F	11%	62.50 55.75 53.25	53.13 43.75 53.63	65.00 59.67 64.58
		57.17 ±4.79	50.17 ±5.56	63.08 ±2.97
	15%	87.75 92.00 77.50	90.50 84.50 90.38	89.25 90.75 92.50
		85.75 ±7.45	88.46 ±3.43	90.83 ±1.63
η_B	11%	84.9 86.7 85.7	84.8 84.9 87.0	87.3 89.0 93.3
		85.77 ±0.90	85.57 ±1.24	89.87 ±3.09
	15%	91.1 93.3 92.5	89.4 89.5 89.5	91.6 91.3 117.7
		92.30 ±1.11	89.47 ±0.06	100.20 ±15.16

TABLE A.17a. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Barley — Machine: N.S.L. - 1

Moisture Content (W.B.) \ Impurity level	5%	10%	15%
11%	30.04 29.62 31.20	29.10 27.34 28.07	29.99 30.05 28.53
	30.29 ±0.82	28.17 ±0.88	29.52 ±0.86
15%	30.22 32.46 32.14	29.81 31.58 31.34	31.95 31.42 31.85
	31.61 ±1.21	30.91 ±0.96	31.74 ±0.28

TABLE A.17b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Barley — Machine: N.S.L. - 1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0	100.00 ±0	100.00 ±0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0	100.00 ±0	100.00 ±0
η_F	11%	80.00 77.50 87.50	67.25 62.25 67.50	83.25 80.25 78.42
		81.67 ±5.20	65.67 ±2.96	80.64 ±2.44
	15%	88.75 109.50 97.75	76.38 94.38 98.63	90.25 89.67 93.83
		98.67 ±10.41	89.79 ±11.81	91.25 ±2.26
η_B	11%	16.6 16.4 17.3	16.7 15.1 15.5	16.3 16.6 14.9
		16.77 ±0.47	15.77 ±0.83	15.93 ±0.91
	15%	16.0 16.7 17.5	16.7 17.1 16.4	18.0 17.4 17.5
		16.73 ±0.75	16.73 ±0.35	17.63 ±0.32

TABLE A.18a. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Barley Machine: N.S.L. - 2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	31.90 29.46 32.62	31.67 31.84 31.48	31.41 31.09 30.29
	31.33 ±1.66	31.66 ±0.18	30.93 ±0.58
15%	34.00 33.26 34.98	33.12 33.57 33.28	32.03 34.52 33.81
	34.08 ±0.86	33.32 ±0.23	33.45 ±1.28

TABLE A.18b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Barley Machine: N.S.L. - 2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0	100.00 ±0	100.00 ±0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0	100.00 ±0	100.00 ±0
η_F	11%	90.25 69.50 87.00	88.13 87.63 82.25	86.92 79.17 79.00
		82.25 ±11.16	86.00 ±3.26	81.69 ±4.52
	15%	100.00 100.00 100.00	96.38 98.88 90.88	81.75 108.67 95.58
		100.00 ±0.00	95.38 ±4.09	95.33 ±13.46
η_B	11%	17.9 17.0 19.1	17.8 18.1 17.6	17.6 18.0 17.0
		18.00 ±1.05	17.83 ±0.25	17.53 ±0.50
	15%	19.5 18.6 20.7	18.8 19.1 19.5	18.9 19.3 19.7
		19.60 ±1.05	19.13 ±0.35	19.30 ±0.40

TABLE A.19a. Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Corn Machine: CD-XT 3-1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	24.60 24.40 26.40	23.80 24.60 24.70	24.00 24.47 24.00
	25.13 ±1.10	24.37 ±0.49	24.16 ±0.27
15%	22.00 22.20 21.60	22.60 22.00 22.80	23.80 23.13 23.47
	21.93 ±0.31	22.47 ±0.42	23.47 ±0.33

TABLE A.19b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Corn Machine: CD-XT 3-1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
	15%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
η_F	11%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
	15%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
η_B	11%	26.74 26.52 28.70	25.87 26.74 26.85	26.09 26.59 26.09
		27.32 ±1.20	26.49 ±0.54	26.26 ±0.29
	15%	23.91 24.13 23.48	24.57 23.91 24.78	25.87 25.14 25.51
		23.84 ±0.33	24.42 ± 0.45	25.51 ±0.36

TABLE A.20a. Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Corn — Machine: CD-XT 3-2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	19.80 20.60 21.20	22.10 22.50 23.40	23.73 23.40 24.00
	20.53 ±0.70	22.67 ±0.67	23.71 ±0.30
15%	21.40 22.00 21.80	22.50 22.80 22.30	23.40 23.00 22.80
	21.73 ±0.31	22.53 ±0.25	23.07 ±0.31

TABLE A.20b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Corn — Machine: CD-XT 3-2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
	15%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
η_F	11%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
	15%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
η_B	11%	21.52 22.39 23.04	24.02 24.46 25.43	25.80 25.43 26.09
		22.32 ±0.76	24.64 ±0.72	25.77 ±0.33
	15%	23.26 23.91 23.70	24.46 24.78 24.24	25.43 25.00 24.78
		23.62 ±0.33	24.49 ±0.27	25.07 ±0.33

TABLE A.21a. Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Corn   Machine: Labofix-1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	40.60	38.70	39.60
	36.60	38.90	38.33
	38.00	35.40	41.80
	38.40 ±2.03	37.67 ±1.97	39.91 ±1.75
15%	40.60	45.50	46.27
	43.60	43.40	46.33
	42.80	44.40	47.67
	42.33 ±1.55	44.43 ±1.05	46.76 ±0.79

TABLE A.21b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Corn   Machine: Labofix-1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00	100.00	100.00
		100.00	100.00	100.00
		100.00	100.00	100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
	15%	100.00	100.00	100.00
		100.00	100.00	100.00
		100.00	100.00	100.00
		100.00 ±0.00	100.00 ±0.00	100.00 ±0.0
η_F	11%	0.00	0.00	0.00
		0.00	0.00	0.00
		0.00	0.00	0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
	15%	0.00	0.00	0.00
		0.00	0.00	0.00
		0.00	0.00	0.00
		0.00 ±0.00	0.00 ±0.00	0.0 ±0.00
η_B	11%	37.6	35.5	36.5
		33.3	35.8	35.1
		34.8	32.0	38.9
		35.23 ±2.18	34.43 ±2.11	36.83 ±1.92
	15%	37.6	42.9	43.8
		40.9	40.7	43.8
		40.0	41.7	45.3
		39.50 ±1.71	41.77 ±1.10	44.30 ±0.87

TABLE A.22a. Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Corn Machine: Labofix-2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	34.60 37.20 35.20	43.00 44.10 43.10	46.87 47.07 43.33
	35.67 ±1.36	43.40 ±0.61	45.76 ±2.10
15%	45.00 44.40 45.20	48.50 45.40 45.60	45.13 47.33 46.73
	44.87 ±0.42	46.50 ±1.74	46.40 ±1.14

TABLE A.22b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Corn Machine: Labofix-2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
η_F	11%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
	15%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
η_B	11%	31.1 33.9 31.7	40.2 41.4 40.3	44.4 44.6 40.6
		32.23 ±1.47	40.63 ±0.67	43.20 ±2.25
	15%	42.4 41.7 42.6	46.2 42.8 43.0	42.5 44.9 44.3
		42.23 ±0.47	44.00 ±1.91	43.90 ±1.25

TABLE A.23a. Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Corn Machine: N.S.L.-1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	14.20 13.00 14.00	14.50 13.50 14.50	15.07 15.40 13.80
	13.73 ±0.64	14.17 ±0.58	14.76 ±0.84
15%	14.00 13.50 14.06	13.23 14.64 14.13	18.52 14.91 14.51
	13.85 ±0.31	14.00 ±0.71	15.98 ±2.21

TABLE A.23b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Corn Machine: N.S.L.-1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	000.00 100.00 100.00
		100.00 ±0.00	100.00 ±0.00	100.00 ±00.00
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
η_F	11%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
	15%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
η_B	11%	8.9 7.6 8.7	9.2 8.2 9.2	9.9 10.2 8.5
		8.40 ±0.70	8.87 ±0.58	9.53 ±0.91
	15%	8.7 8.2 8.8	7.9 9.4 8.8	13.6 9.7 9.3
		8.57 ±0.32	8.70 ±0.75	10.87 ±2.38

TABLE A.24a. Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Corn Machine: N.S.L.-2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	14.00 14.40 14.40	13.80 13.80 14.10	14.87 13.40 15.73
	14.27 ±0.23	13.90 ±0.17	14.67 ±1.18
15%	12.82 14.74 14.36	13.02 13.93 14.02	14.98 15.12 14.23
	13.97 ±1.02	13.66 ±0.55	14.78 ±0.48

TABLE A.24b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Corn Machine: N.S.L.-2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
η_F	11%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
	15%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
η_B	11%	9.6 9.1 9.1	8.5 8.5 9.6	9.6 8.0 10.6
		9.27 ±0.29	8.87 ±0.64	9.40 ±1.31
	15%	7.4 9.5 9.1	7.6 8.6 8.7	9.8 9.9 8.9
		8.67 ±1.12	8.30 ±0.61	9.53 ±0.55

TABLE A.25a. Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Soybeans Machine: CD-XT 3-1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	3.80 4.00 4.00	3.70 3.70 3.80	3.80 3.60 3.73
	3.93 ±0.12	3.73 ±0.06	3.71 ±0.10
15%	3.60 3.60 3.80	3.60 3.80 3.70	3.93 3.53 4.00
	3.67 ±0.12	3.70 ±0.10	3.82 ±0.25

TABLE A.25b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Soybeans Machine: CD-XT 3-1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	60.00 60.00 60.00	60.00 50.00 60.00	60.00 56.67 56.67
		60.00 ±0.00	56.67 ±5.77	57.78 ±1.92
	15%	80.00 80.00 80.00	65.00 75.00 70.00	80.00 73.33 80.00
		80.00 ±0.00	70.00 ±5.00	77.78 ±3.85
η_F	11%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
	15%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
η_B	11%	2.65 2.86 2.86	2.55 2.76 2.65	2.65 2.52 2.65
		2.79 ±0.12	2.65 ±0.10	2.61 ±0.08
	15%	2.04 2.04 2.24	2.35 2.35 2.35	2.38 2.11 2.45
		2.11 ±0.12	2.35 ±0.00	2.31 ±0.18

TABLE A.26a. Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Soybeans Machine: CD-XT 3-2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	4.20 3.60 3.80	4.10 3.80 3.80	3.93 3.67 3.80
	3.87 ±0.31	3.90 ±0.17	3.80 ±0.13
15%	4.20 3.80 4.00	4.10 4.00 4.20	3.93 4.20 4.00
	4.00 ±0.20	4.10 ±0.10	4.04 ±0.14

TABLE A.26b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Soybeans Machine: CD-XT 3-2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	70.00 60.00 60.00	65.00 60.00 65.00	63.33 60.00 66.67
		63.33 ±5.77	63.33 ±2.89	63.33 ±3.33
	15%	100.00 100.00 100.00	105.00 100.00 100.00	96.67 103.33 100.00
		100.00 ±0.00	101.67 ±2.89	100.00 ±3.33
η_F	11%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
	15%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
η_B	11%	2.86 2.45 2.65	2.86 2.65 2.55	2.72 2.52 2.52
		2.65 ±0.20	2.69 ±0.16	2.59 ±0.12
	15%	2.24 1.84 2.04	2.04 2.04 2.24	2.04 2.18 2.04
		2.04 ±0.20	2.11 ±0.12	2.09 ±0.08

TABLE A.27a. Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Soybeans Machine: Labofix-1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	102.60 100.20 102.80	101.90 101.80 100.80	100.80 100.87 100.73
	101.87 ±1.45	101.50 ±0.61	100.80 ±0.06
15%	100.60 100.80 100.60	100.10 95.40 100.20	100.13 99.93 99.40
	100.67 ±0.11	98.57 ±2.74	99.82 ±0.38

TABLE A.27b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Soybeans Machine: Labofix-1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
η_F	11%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
	15%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
η_B	11%	102.7 100.2 102.9	101.9 101.8 100.8	100.8 100.9 100.7
		101.93 ±1.50	101.50 ±0.61	100.80 ±0.10
	15%	100.6 100.8 100.6	100.1 95.3 100.2	100.1 99.9 99.4
		100.67 ±0.12	98.53 ±2.80	99.8 ±0.36

TABLE A.28a. Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Soybeans Machine: Labofix-2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	101.80 101.60 102.00	101.50 101.50 100.90	100.73 100.60 101.27
	101.80 ±0.20	101.30 ±0.34	100.87 ±0.35
15%	100.40 100.80 100.00	99.70 99.80 100.30	99.87 96.13 99.40
	100.40 ±0.40	99.93 ±0.32	98.47 ±2.03

TABLE A.28b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Soybeans Machine: Labofix-2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
η_F	11%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
	15%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
η_B	11%	101.8 101.6 102.0	101.5 101.5 100.9	100.7 100.6 101.3
		101.80 ±0.20	101.30 ±0.35	100.87 ±0.38
	15%	100.4 100.8 100.0	99.7 99.8 100.3	99.9 96.1 99.4
		100.40 ±0.40	99.93 ±0.32	98.47 ±2.06

TABLE A.29a. Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Soybeans Machine: N.S.L.-1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	64.60 60.80 61.20	63.00 63.60 61.20	63.13 60.27 60.00
	62.20 ±2.09	62.60 ±1.25	61.13 ± 1.74
15%	57.60 53.40 57.20	60.30 56.70 60.20	58.13 58.53 58.07
	56.07 ±2.32	59.07 ±2.05	58.24 ±0.25

TABLE A.29b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Soybeans Machine: N.S.L.-1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
η_F	11%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
	15%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
η_B	11%	63.9 60.0 60.4	62.2 62.9 60.4	62.4 59.5 59.2
		61.43 ±2.15	61.83 ±1.29	60.37 ±1.77
	15%	56.7 52.4 54.3	59.5 55.8 59.4	57.3 57.7 57.2
		54.47 ±2.15	58.23 ±2.11	57.4 ±0.26

TABLE A.30a. Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Soybeans Machine: N.S.L.-2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	55.00 56.60 53.80	55.90 58.00 56.20	57.20 57.60 56.20
	55.13 ±1.40	56.70 ±1.14	57.00 ±0.72
15%	52.60 55.20 52.60	53.00 52.50 53.40	54.60 52.07 54.13
	53.47 ±1.50	52.97 ±0.45	53.60 ±1.35

TABLE A.30b. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Soybeans Machine: N.S.L.-2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
η_F	11%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
	15%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
η_B	11%	54.1 55.7 52.9	55.0 57.1 55.3	56.3 56.7 55.3
		54.23 ±1.40	55.8 ±1.14	56.1 ±0.72
	15%	51.6 54.3 51.6	52.0 51.5 52.4	53.7 51.1 53.2
		52.50 ±1.56	51.97 ±0.45	52.67 ±1.38

TABLE A.31. Statistical Analysis for the Moisture Content Effect on the Overall Removal Efficiency

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRW Wheat	S	NS	NS	NS	S	S
Durum Wheat	S	S	NS	S	S	S
Barley	NS	S	S	S	S	NS
Corn	S	S	NS	NS	S	NS
Soybeans	NS	S	S	S	NS	S

S = Statistically significant
NS = Statistically not significant
$\alpha = 0.05$

TABLE A.32. Statistical Analysis for the Impurity Level Effect on the Overall Removal Efficiency

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRW Wheat	S	NS	NS	NS	NS	NS
Durum Wheat	NS	NS	NS	S	NS	NS
Barley	S	S	NS	NS	NS	NS
Corn	NS	S	NS	NS	NS	S
Soybeans	NS	NS	NS	NS	NS	NS

S = Statistically significant
NS = Statistically not significant
$\alpha = 0.05$

TABLE A.33. Statistical Analysis for Units Effect on the Overall Removal Efficiency

Model / Crop	Labofix	N.S.L.	CD-XT 3
HRW Wheat	S	S	NS
Durum Wheat	S	NS	NS
Barley	S	S	S
Corn	S	NS	S
Soybeans	NS	S	NS

S = Statistically significant
NS = Statistically not significant
$\alpha = 0.05$

TABLE A.34. Statistical Analysis for the Three Replicates on the Overall Removal Efficiency

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRW Wheat	NS	NS	NS	NS	NS	NS
Durum Wheat	NS	NS	NS	NS	NS	NS
Barley	NS	S	NS	NS	NS	NS
Corn	NS	NS	NS	NS	NS	S
Soybeans	NS	NS	NS	NS	NS	NS

S = Statistically significant
NS = Statistically not significant
$\alpha = 0.05$

TABLE A.35. Statistical Analysis for the Moisture Content Effect on the Removal Efficiency of Light Materials

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRW Wheat	NS*	NS*	NS*	NS*	S	S
Durum Wheat	NS*	NS*	NS*	NS*	S	S
Barley	NS*	NS*	NS*	NS*	S	S
Corn	NS*	NS*	NS*	NS*	xxx	xxx
Soybeans	NS*	NS*	NS*	NS*	S	S

* Analysis based on adjusted data
xxx No materials removed
S = Statistically significant
NS = Statistically not significant
$\alpha = 0.05$

TABLE A.36. Statistical Analysis for the Impurity Level Effect on the Removal Efficiency of Light Materials

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRW Wheat	NS*	NS*	NS*	NS*	NS	S
Durum Wheat	NS*	NS*	NS*	NS*	S	NS
Barley	NS*	NS*	NS*	NS*	NS	NS
Corn	NS*	NS*	NS*	NS*	xxx	xxx
Soybeans	NS*	NS*	NS*	NS*	NS	NS

* Analysis based on adjusted data.
xxx No materials removed
S = Statistically significant
NS = Statistically not significant
$\alpha = 0.05$

TABLE A.37. Statistical Analysis for Units Effect on the Removal Efficiency of Light Materials

Model / Crop	Labofix	N.S.L.	CD-XT 3
HRW Wheat	NS*	NS*	S
Durum Wheat	NS*	NS*	S
Barley	NS*	NS*	S
Corn	NS*	NS*	xxx
Soybeans	NS*	NS*	S

* Analysis based on adjusted data
xxx No materials removed
S = Statistically significant
NS = Statistically not significant
$\alpha = 0.05$

TABLE A.38. Statistical Analysis for the Three Replicates on the Removal Efficiency of Light Materials

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRW Wheat	NS*	NS*	NS*	NS*	NS	NS
Durum Wheat	NS*	NS*	NS*	NS*	NS	NS
Barley	NS*	NS*	NS*	NS*	NS	NS
Corn	NS*	NS*	NS*	NS*	xxx	xxx
Soybeans	NS*	NS*	NS*	NS*	NS	NS

* Analysis based on adjusted data
xxx No materials removed
S = Statistically significant
NS = Statistically not significant
$\alpha = 0.05$

TABLE A.39. Statistical Analysis for the Moisture Content Effect on the Removal Efficiency of Foreign Materials

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRW Wheat	NS	NS	NS	NS	S	S
Durum Wheat	NS	NS	NS	NS	NS	NS
Barley	S	S	S	S	S	S
Corn	xxx	xxx	xxx	xxx	xxx	xxx
Soybeans	xxx	xxx	xxx	xxx	xxx	xxx

xxx No materials removed
S = Statistically significant
NS = Statistically not significant
$\alpha = 0.05$

TABLE A.40. Statistical Analysis for the Impurity Level Effect on the Removal Efficiency of Foreign Materials

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRW Wheat	NS	NS	NS	NS	NS	NS
Durum Wheat	NS	NS	S	NS	S	NS
Barley	NS	S	NS	NS	NS	NS
Corn	xxx	xxx	xxx	xxx	xxx	xxx
Soybeans	xxx	xxx	xxx	xxx	xxx	xxx

xxx No materials removed.
S = Statistically significant
NS = Statistically not significant
$\alpha = 0.05$

TABLE A.41. Statistical Analysis for Units Effect on the Removal Efficiency of Foreign Materials

Model / Crop	Labofix	N.S.L.	CD-XT 3
HRW Wheat	NS	NS	NS
Durum Wheat	NS	NS	NS
Barley	S	S	S
Corn	xxx	xxx	xxx
Soybeans	xxx	xxx	xxx

S = Statistically significant
NS = Statistically not significant
$\alpha = 0.05$

TABLE A.42. Statistical Analysis for the Three Replicates on the Removal Efficiency of Foreign Materials

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRW Wheat	S	NS	NS	NS	NS	NS
Durum Wheat	NS	NS	NS	NS	NS	S
Barley	NS	NS	NS	NS	NS	NS
Corn	xxx	xxx	xxx	xxx	xxx	xxx
Soybeans	xxx	xxx	xxx	xxx	xxx	xxx

S = Statistically significant
NS = Statistically not significant
$\alpha = 0.05$

TABLE A.43. Statistical Analysis for the Moisture Content Effect on the Removal Efficiency of Broken Kernels

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRW Wheat	S	NS	NS	NS	NS	NS
Durum Wheat	S	S	NS	S	S	S
Barley	NS	S	S	S	S	S
Corn	S	S	NS	NS	S	NS
Soybeans	NS	S	S	S	S	S

S = Statistically significant
NS = Statistically not significant
$\alpha = 0.05$

TABLE A.44. Statistical Analysis for the Impurity Level Effect on the Removal Efficiency of Broken Kernels

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRW Wheat	S	NS	NS	NS	NS	NS
Durum Wheat	NS	NS	NS	S	NS	NS
Barley	S	NS	NS	NS	NS	NS
Corn	NS	S	NS	NS	NS	S
Soybeans	NS	NS	NS	NS	S	NS

S = Statistically significant
NS = Statistically not significant
$\alpha = 0.05$

TABLE A.45. Statistical Analysis for Units Effect on the Removal Efficiency of Broken Kernels

Model / Crop	Labofix	N.S.L.	CD-XT 3
HRW Wheat	S	S	NS
Durum Wheat	S	NS	NS
Barley	S	S	NS
Corn	S	NS	S
Soybeans	NS	S	NS

S = Statistically significant
NS = Statistically not significant
$\alpha = 0.05$

TABLE A.46. Statistical Analysis for the Three Replicates on the Removal Efficiency of Broken Kernels

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRW Wheat	NS	NS	NS	NS	NS	NS
Durum Wheat	NS	NS	NS	NS	NS	NS
Barley	NS	NS	NS	S	NS	NS
Corn	NS	NS	NS	NS	NS	S
Soybeans	NS	NS	NS	NS	S	NS

S = Statistically significant
NS = Statistically not significant
$\alpha = 0.05$

TABLE A.47. Summary Table on Removal Efficiencies for Hard Red Winter Wheat

Model			Removal Efficiency (%)			
			Overall	Light Materials	Foreign Materials	Broken Kernels
Lab	Unit 1	$\bar{x} \pm S$	77.29 ± 6.97	100.00 ± 0.00	48.53 ± 9.20	78.87 ± 7.72
		Ranges	68.1 ~ 96.6	100.00	32.5 ~ 70.9	68.9 ~ 100.7
	Unit 2	$\bar{x} \pm S$	85.91 ± 6.05	100.00 ± 0.0	45.63 ± 8.14	88.81 ± 6.62
		Ranges	77.3 ~ 100.0	100.0	30.0 ~ 58.3	80.2 ~ 110.7
NSL	Unit 1	$\bar{x} \pm S$	20.01 ± 2.03	99.21 ± 2.36	45.87 ± 9.19	14.06 ± 2.37
		Ranges	16.3 ~ 22.7	91.5 ~ 100.0	35.5 ~ 72.0	10.6 ~ 17.5
	Unit 2	$\bar{x} \pm S$	36.41 ± 6.45	100.00 ± 0.00	48.79 ± 9.88	32.41 ± 7.30
		Ranges	28.9 ~ 48.3	100.0	31.3 ~ 65.8	25.0 ~ 47.3
CD	Unit 1	$\bar{x} \pm S$	11.49 ± 1.37	40.54 ± 19.98	92.81 ± 7.66	2.79 ± 0.74
		Ranges	9.43 ~ 13.73	17.3 ~ 9.10	73.4 ~ 103.8	1.8 ~ 4.5
	Unit 2	$\bar{x} \pm S$	12.17 ± 0.99	50.40 ± 11.91	93.37 ± 6.96	3.06 ± 0.63
		Ranges	9.9 ~ 13.3	31.5 ~ 74.8	75.6 ~ 101.8	2.4 ~ 4.3

TABLE A.48. Summary Table on Removal Efficiencies for Durum

Model			Removal Efficiency (%)			
			Overall	Light Materials	Foreign Materials	Broken Kernels
Lab	Unit 1	$\overline{x} \pm S$	68.70 ± 8.58	100.00 ± 0.00	66.57 ± 7.47	68.09 ± 8.87
		Ranges	57.6 ~ 77.5	100.0	60.0 ~ 80.0	48.6 ~ 77.2
	Unit 2	$\overline{x} \pm S$	76.18 ± 8.79	100.00 ± 0.00	67.41 ± 8.92	75.88 ± 9.13
		Ranges	60.4 ~ 85.6	100.0	53.3 ~ 90.0	59.4 ~ 85.4
NSL	Unit 1	$\overline{x} \pm S$	21.04 ± 0.64	100.00 ± 0.00	64.62 ± 8.20	18.50 ± 0.66
		Ranges	19.9 ~ 22.0	100.0	53.3 ~ 80.0	17.5 ~ 19.5
	Unit 2	$\overline{x} \pm S$	21.24 ± 1.28	100.00 ± 0.00	65.46 ± 9.82	18.73 ± 1.35
		Ranges	18.9 ~ 23.2	100.0	53.3 ~ 85.0	16.5 ~ 21.5
CD	Unit 1	$\overline{x} \pm S$	17.57 ± 0.25	69.09 ± 5.13	97.69 ± 4.00	14.85 ± 0.29
		Ranges	17.1 ~ 18.0	60.0 ~ 80.0	93.3 ~ 100.0	14.4 ~ 15.2
	Unit 2	$\overline{x} \pm S$	17.64 ± 0.27	77.69 ± 6.96	96.76 ± 4.87	14.74 ± 0.29
		Ranges	17.2 ~ 18.0	60.0 ~ 90.0	85.0 ~ 0.0	14.4 ~ 15.1

TABLE A.49. Summary Table on Removal Efficiencies for Barley

Model			Removal Efficiency (%)			
			Overall	Light Materials	Foreign Materials	Broken Kernels
Lab	Unit 1	$\overline{x} \pm S$	87.46 ± 2.44	100.00 ± 0.00	84.92 ± 8.34	86.21 ± 3.10
		Ranges	83.8 ~ 91.0	100.0	69.3 ~ 96.6	81.7 ~ 90.7
	Unit 2	$\overline{x} \pm S$	88.94 ± 3.68	100.00 ± 0.00	72.59 ± 17.20	90.53 ± 7.37
		Ranges	83.1 ~ 93.9	100.00	43.8 ~ 92.5	84.8 ~ 117.7
NSL	Unit 1	$\overline{x} \pm S$	30.37 ± 1.49	100.00 ± 0.00	84.63 ± 12.23	16.59 ± 0.84
		Ranges	27.3 ~ 32.5	100.0	62.3 ~ 109.5	14.9 ~ 18.0
	Unit 2	$\overline{x} \pm S$	32.47 ± 1.47	100.00 ± 0.00	90.12 ± 9.74	18.57 ± 1.01
		Ranges	29.5 ~ 35.0	100.0	69.5 ~ 108.7	17.0 ~ 20.7
CD	Unit 1	$\overline{x} \pm S$	36.23 ± 2.47	84.06 ± 4.23	81.84 ± 16.94	25.96 ± 1.01
		Ranges	33.2 ~ 39.4	75.0 ~ 89.4	58.3 ~ 100.8	24.6 ~ 27.4
	Unit 2	$\overline{x} \pm S$	36.92 ± 0.65	69.16 ± 12.66	92.09 ± 7.24	27.62 ± 1.19
		Ranges	35.7 ~ 38.0	50.2 ~ 82.8	77.3 ~ 104.5	25.3 ~ 29.2

TABLE A.50. Summary Table on Removal Efficiencies for Yellow Dent Corn

Model			Removal Efficiency (%)			
			Overall	Light Materials	Foreign Materials	Broken Kernels
Lab	Unit 1	$\bar{x} \pm S$	41.58 ± 3.61	100.00 ± 0.00	**	38.68 ± 3.92
		Ranges	35.4 ~ 47.7	100.0	**	32.0 ~ 45.3
	Unit 2	$\bar{x} \pm S$	44.22 ± 3.15	100.0 ± 0.00	**	41.03 ± 4.40
		Ranges	36.6 ~ 48.5	100.0	**	31.1 ~ 46.2
NSL	Unit 1	$\bar{x} \pm S$	14.41 ± 1.20	100.00 ± 0.00	**	9.16 ± 1.30
		Ranges	13.0 ~ 18.5	100.0	**	7.6 ~ 13.6
	Unit 2	$\bar{x} \pm S$	14.20 ± 0.73	100.00 ± 0.00	**	8.79 ± 1.12
		Ranges	12.8 ~ 15.7	100.0	**	5.7 ~ 10.6
CD	Unit 1	$\bar{x} \pm S$	23.58 ± 1.24	*	**	25.57 ± 1.42
		Ranges	21.6 ~ 26.4	*	**	23.5 ~ 26.9
	Unit 2	$\bar{x} \pm S$	22.37 ± 1.11	*	**	24.32 ± 1.21
		Ranges	19.8 ~ 24.0	*	**	21.5 ~ 26.1

* Aspiration not turned on
** No materials removed

TABLE A.51. Summary Table on Removal Efficiencies for Soybeans

Model			Removal Efficiency (%)			
			Overall	Light Materials	Foreign Materials	Broken Kernels
Lab	Unit 1	$\overline{x} \pm S$	100.55 ± 1.57	100.00 ± 0.00	**	100.54 ± 1.61
		Ranges	95.4 ~ 102.6	100.0	**	95.3 ~ 102.9
	Unit 2	$\overline{x} \pm S$	100.46 ± 1.34	100.00 ± 0.00	**	100.46 ± 1.34
		Ranges	96.1 ~ 102.0	100.0	**	96.1 ~ 102.0
NSL	Unit 1	$\overline{x} \pm S$	59.90 ± 2.81	100.00 ± 0.00	**	58.96 ± 3.03
		Ranges	53.4 ~ 64.6	100.0	**	52.4 ~ 63.9
	Unit 2	$\overline{x} \pm S$	54.82 ± 1.90	100.00 ± 0.00	**	53.88 ± 1.94
		Ranges	52.1 ~ 58.0	100.0	**	51.1 ~ 57.1
CD	Unit 1	$\overline{x} \pm S$	3.76 ± 0.15	67.04 ± 10.17	**	2.49 ± 0.28
		Ranges	3.5 ~ 4.0	50.0 ~ 80.0	**	2.0 ~ 2.9
	Unit 2	$\overline{x} \pm S$	3.97 ± 0.22	81.48 ± 18.86	**	2.36 ± 0.34
		Ranges	3.6 ~ 4.5	60.0 ~ 100.0	**	1.8 ~ 2.9

** No materials removed

TABLE A.52. Broken/Sound Kernel Fractions Separated by Mechanical Shaker (g/g)

Grain Type: Hard Red Winter Wheat   Machine: CD-XT 3 - 1

Moisture Content % (W.B.)	Impurity level (%)		
	5	10	15
11	5.33 / 243.68	10.73 / 237.57	15.28 / 231.31
15	4.86 / 242.75	9.77 / 234.75	14.70 / 230.02

Grain Type: Hard Red Winter Wheat   Machine: CD-XT 3 - 2

Moisture Content % (W.B.)	Impurity level (%)		
	5	10	15
11	4.99 / 244.09	10.70 / 236.79	15.81 / 229.09
15	5.20 / 241.21	10.31 / 234.91	14.57 / 228.10

TABLE A.53. Broken/Sound Kernel Fractions Separated by Mechanical Shaker (g/g)

Grain Type: Durum Machine: CD-XT 3-1

Moisture Content % (W.B.)	Impurity level (%)		
	5	10	15
11	$\frac{2.6}{245.5}$	$\frac{5.2}{240.0}$	$\frac{7.1}{232.3}$
15	$\frac{2.3}{242.4}$	$\frac{4.3}{238.7}$	$\frac{6.7}{235.3}$

Grain Type: Durum Machine: CD-XT 3-2

Moisture Content % (W.B.)	Impurity level (%)		
	5	10	15
11	$\frac{2.3}{242.8}$	$\frac{4.7}{236.8}$	$\frac{7.3}{232.7}$
15	$\frac{2.3}{244.1}$	$\frac{4.8}{239.4}$	$\frac{6.5}{236.1}$

TABLE A.54. Broken/Sound Kernel Fractions Separated by Mechanical Shaker (g/g)

Grain Type: Barley Machine: CD-XT 3 - 1

Moisture Content % (W.B.)	Impurity level (%)		
	5	10	15
11	$\frac{3.71}{240.56}$	$\frac{6.29}{231.88}$	$\frac{9.07}{223.97}$
15	$\frac{5.30}{236.03}$	$\frac{7.21}{229.80}$	$\frac{9.26}{224.21}$

Grain Type: Barley Machine: CD-XT 3 - 2

Moisture Content % (W.B.)	Impurity level (%)		
	5	10	15
11	$\frac{3.91}{239.15}$	$\frac{7.52}{229.56}$	$\frac{10.27}{229.93}$
15	$\frac{4.95}{238.32}$	$\frac{7.28}{231.92}$	$\frac{10.14}{225.50}$

TABLE A.55. Data for Hard Red Winter Wheat from the Kansas State Grain Inspection Service

Identification of sample	Moisture Content (%)	Test weight per bushel (lbs)	Dockage (%)	Foreign material (%)	Shrunken and/or broken kernels (%)	Broken kernels, foreign materials & other grains (%)	Damaged kernels (%)	U.S. No.
WIM11I5	11.6	61.7	0.6	0.1	2.5	2.6	0.5	2 hard red winter wheat
WIM11I10	11.6	61.2	1.2	0.0	4.1	4.1	0.8	2 hard red winter wheat
WIM11I15	11.2	61.1	1.9	0.0	6.8	6.8	0.9	3 hard red winter wheat
WIM15I5	14.6	57.2	0.6	0.0	2.2	2.2	12.7	5 hard red winter wheat
WIM15I10	14.6	57.3	1.2	0.1	4.0	4.1	12.5	5 hard red winter wheat
WIM15I15	14.4	57.5	1.9	0.0	6.1	6.1	13.2	5 hard red winter wheat

TABLE A.56. Data for Durum from the Kansas State Grain Inspection Service

Identification of sample	Moisture Content (%)	Test weight per bushel (lbs)	Dockage (%)	Foreign material (%)	Shrunken and/or broken kernels (%)	Broken kernels, foreign materials & other grains (%)	Damaged kernels (%)	U.S. No.
DUM11I5	11.0	57.4	0.8	0.1	1.1	1.2	0.4	3 hard amber durum wheat
DUM11I10	10.7	58.3	1.7	0.2	2.2	2.4	0.8	2 hard amber durum wheat
DUM11I15	11.2	57.3	2.5	0.2	3.2	3.4	0.7	3 hard amber durum wheat
DUM15I5	14.1	56.5	0.9	0.0	1.0	1.0	0.8	3 hard amber durum wheat
DUM15I10	15.5	54.0	1.8	0.1	1.5	1.6	0.4	4 hard amber durum wheat
DUM15I15	15.3	54.5	2.5	0.2	2.9	3.1	0.9	4 hard amber durum wheat

TABLE A.57. Data for Barley from the Kansas State Grain Inspection Service

Identification of sample	Moisture Content (%)	Test weight per bushel (lbs)	Dockage (%)	Foreign material (%)	Shrunken and/or broken kernels (%)	Broken kernels, foreign materials & other grains (%)	Damaged kernels (%)	U.S. No.
BaM11I5	11.3	48.0	1.0	0.0	2.5 + 1.8 (thin barley)		1.8	1 six rowed barley
BaM11I10	11.3	48.5	2.0	0.2	5.2 + 3.2 (thin barley)		1.5	2 six rowed barley
BaM11I15	11.2	48.0	4.0	0.3	5.6 + 4.8 (thin barley)		0.1	2 six rowed barley
BaM15I5	14.3	48.0	1.0	0.1	2.3 + 1.6 (thin barley)		1.6	1 six rowed barley
BaM15I10	14.2	48.0	3.0	0.1	5.0 + 3.1 (thin barley)		0.4	2 six rowed barley
BaM15I15	14.3	48.0	4.0	0.1	4.2 + 6.6 (thin barley)		0.7	2 six rowed barley

TABLE A.58. Data for Corn from the Kansas State Grain Inspection Service

Identification of sample	Moisture Content (%)	Test weight per bushel (lbs)	Dockage (%)	Foreign material (%)	Shrunken and/or broken kernels (%)	Broken kernels, foreign materials & other grains (%)	Damaged kernels (%)	U.S. No.
COM11I5	11.4	58.5		0.3	1.1	1.4	0.5	1 yellow corn
COM11I10	11.6	58.0		0.5	1.9	2.4	1.2	2 yellow corn
COM11I15	11.6	58.0		0.8	2.9	3.7	1.7	3 yellow corn
COM15I5	15.1	56.5		0.3	0.8	1.1	1.3	1 yellow corn
COM15I10	15.4	56.0		0.7	1.5	2.2	3.4	2 yellow corn
COM15I15	15.4	56.0		1.0	2.2	3.2	4.5	3 yellow corn

TABLE A.59. Data for Soybeans from the Kansas State Grain Inspection Service

Identification of sample	Moisture Content (%)	Test weight per bushel (lbs)	Dockage (%)	Foreign material (%)	Shrunken and/or broken kernels (%)	Splits (%)	Damaged kernels (%)	U.S. No.
SOM11I5	11.6	56.5		0.2		4.0	0.4	1 yellow soybeans
SOM11I10	11.4	56.5		0.4		9.0	0.8	1 yellow soybeans
SOM11I15	11.4	56.5		0.5		16.0	0.4	2 yellow soybeans
SOM15I5	14.9	54.5		0.2		6.0	0.5	2 yellow soybeans
SOM15I10	14.9	54.5		0.2		10.0	1.2	2 yellow soybeans
SOM15I15	14.9	54.5		0.4		15.0	0.8	2 yellow soybeans

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EVALUATION OF LABORATORY MODEL GRAIN CLEANING AND SEPARATING EQUIPMENT (Part I)

by

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ABSTRACT

Two laboratory grain cleaners, Model Labofix from W. Germany, and Model N.S.L. from France, were selected in an earlier study as promising models from throughout of the world based on a literature review and survey. These two cleaners are tested with five types of U.S. grains (HRW wheat, durum wheat, barley, corn, and soybeans), with a reference grain cleaning equipment, Carter Day Dockage tester XT3(CD-XT3), which is currently used in the U.S. grain grading system. The major objective of this research was to test, analyze, and evaluate whether or not these three laboratory grain cleaning models will be applicable for the grain grading system in the United States.

The evaluation of these three models was maily based on the removal efficiencies of impurities. The average values of overall removal efficiencies for Labofix, N.S.L., and CD-XT3, respectively were: 81.6%, 28.2%, and 11.8% for HRW wheat; 72.4%, 21.1%, and 17.6% for durum wheat; 88.2%, 31.4%, and 36.6% for barley; 42.9%, 14.3%, and 23.0% for yellow dent corn; and 100%, 57.4%, and 3.9% for soybeans.

The statistical analysis showed that the difference between the three models tested was significant. It also showed that the moisture content had a more significant effect on the overall removal efficiency than the impurity level effect. The results showed that no model was perfect for all five crops tested with respect to the overall removal efficiencies. However, among the three models tested, the Labofix model had the highest values on overall removal efficiency for every crop. It was found that the CD-XT3 model had better reproducibility, shorter testing time, but higher noise level than the other two models with the five crops tested.

A good linear relation between the test results and those by the KSGIS was obtained. Comparing the data from KSGIS, the Labofix model separated an amount equal to or more impurities from given samples; the CD-XT3 model separated about an equal amount of impurities from the corn sample, but it separated much less for other crops; the N.S.L. model separated less from every crop.